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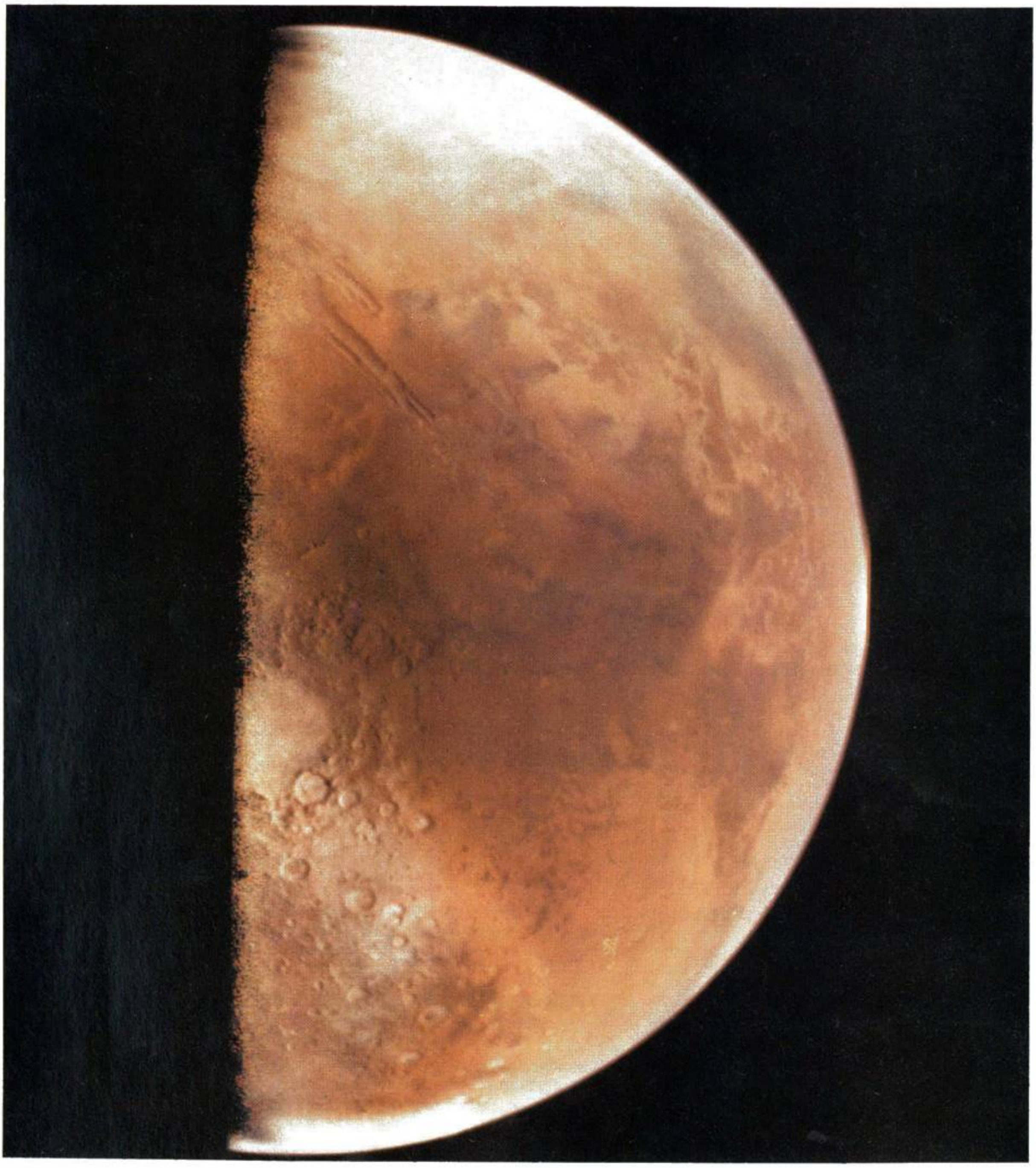

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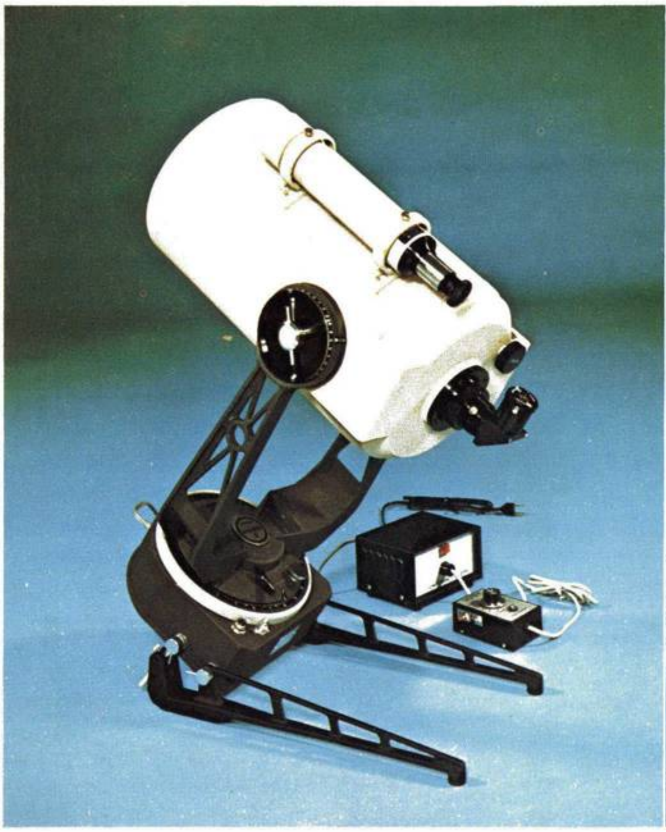

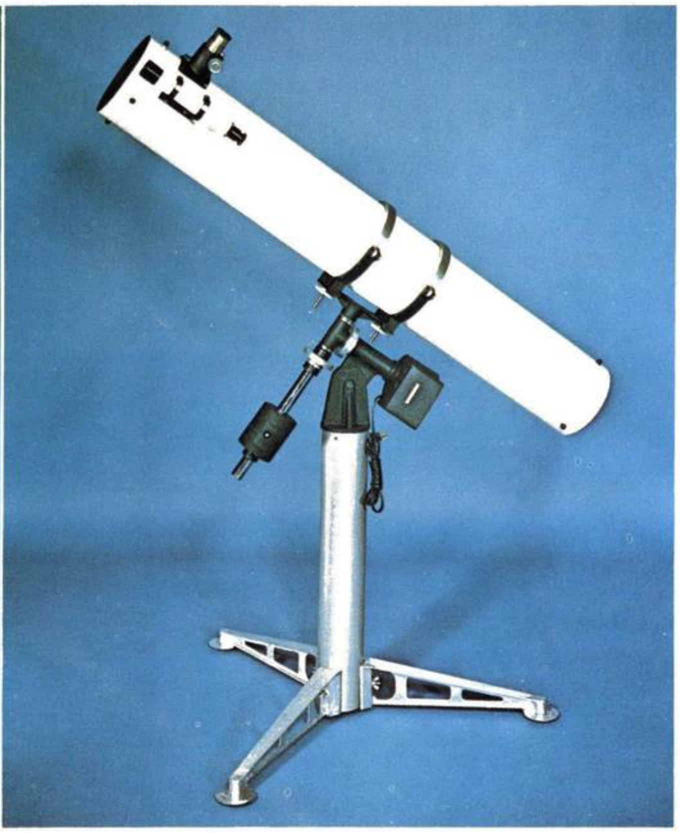

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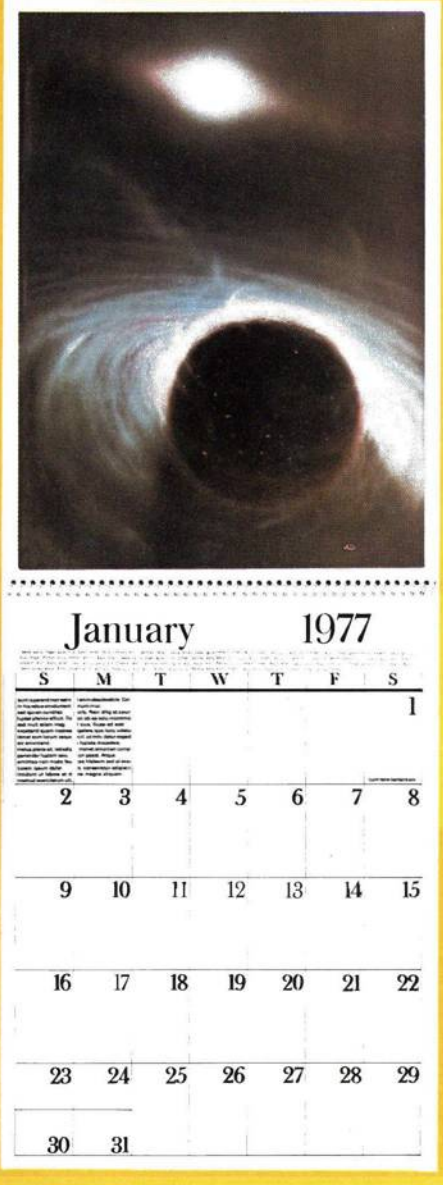

January 1977

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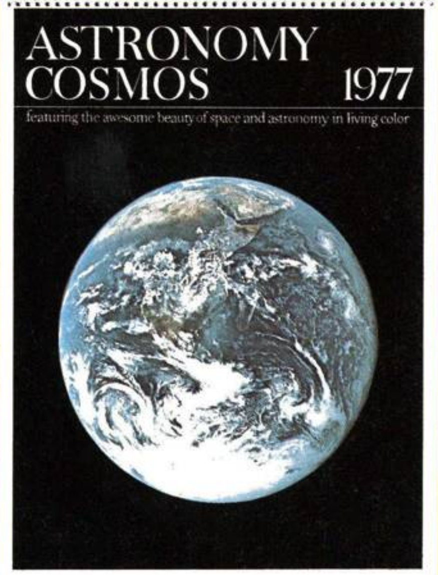
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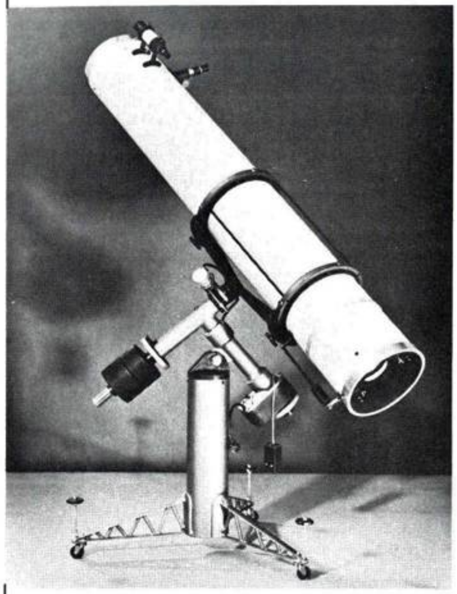

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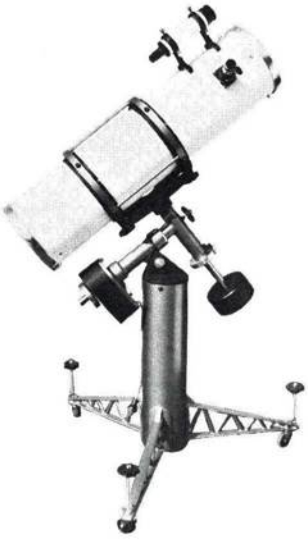

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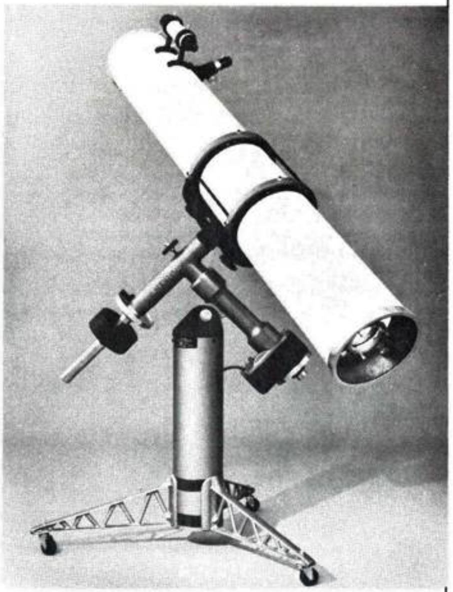

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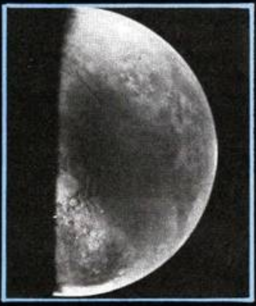

Cover

This photo of the red planet Mars, recorded by the robot eyes of NASA's Viking 1 spacecraft, reveals far more than Earthbound observers have ever seen. This month, ASTRONOMY is devoted to Mars: the recent findings and the ambiguous answer to the centuries-old question of life on Mars. We invite you to orbit Mars on the two Viking spacecraft, and land on the surface. Study the orange-red rock covered plains and ancient sand dunes with us, and look at Mars' strange pink sky. In Mars, we now have a third world to explore. NASA photograph.

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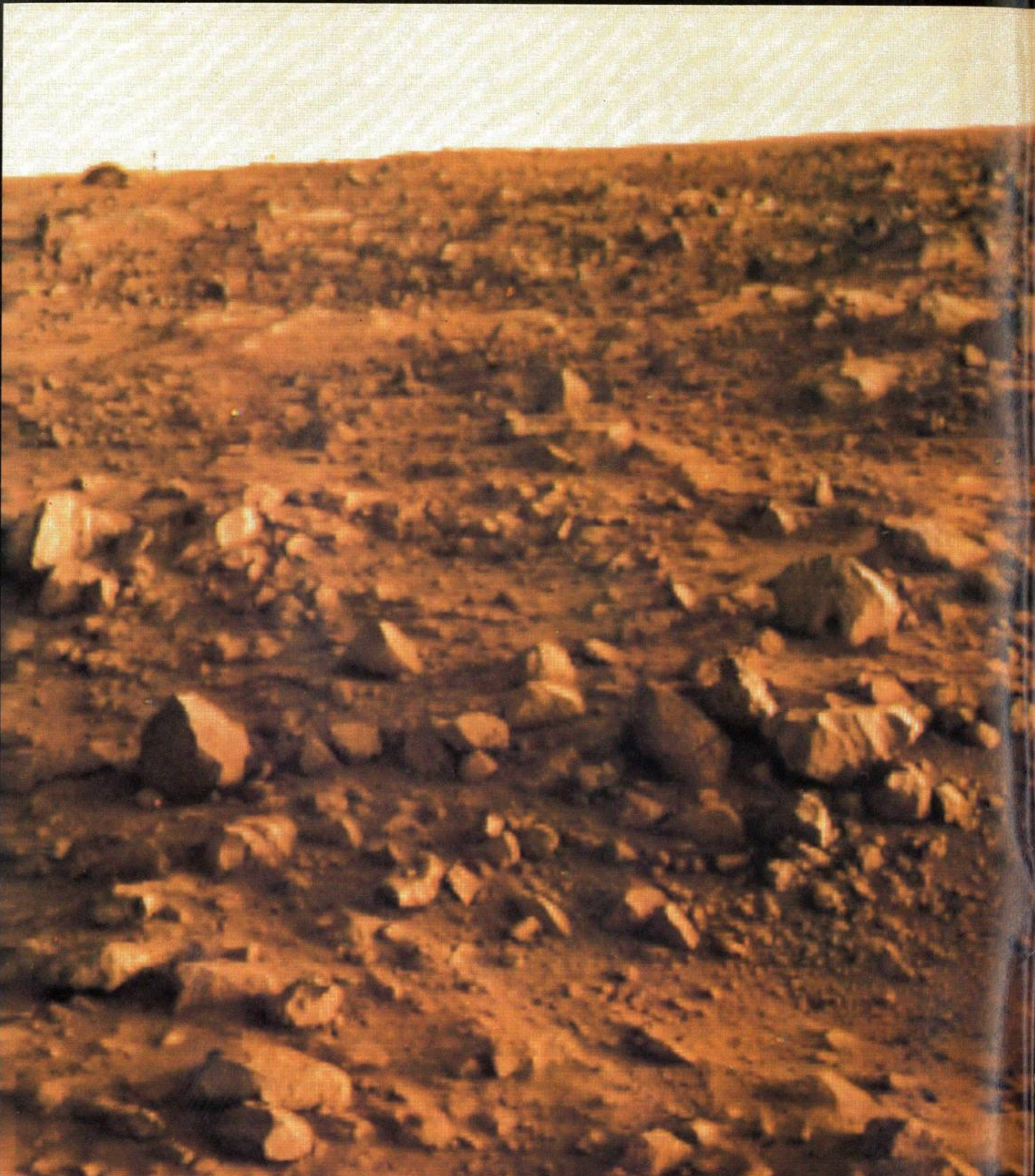
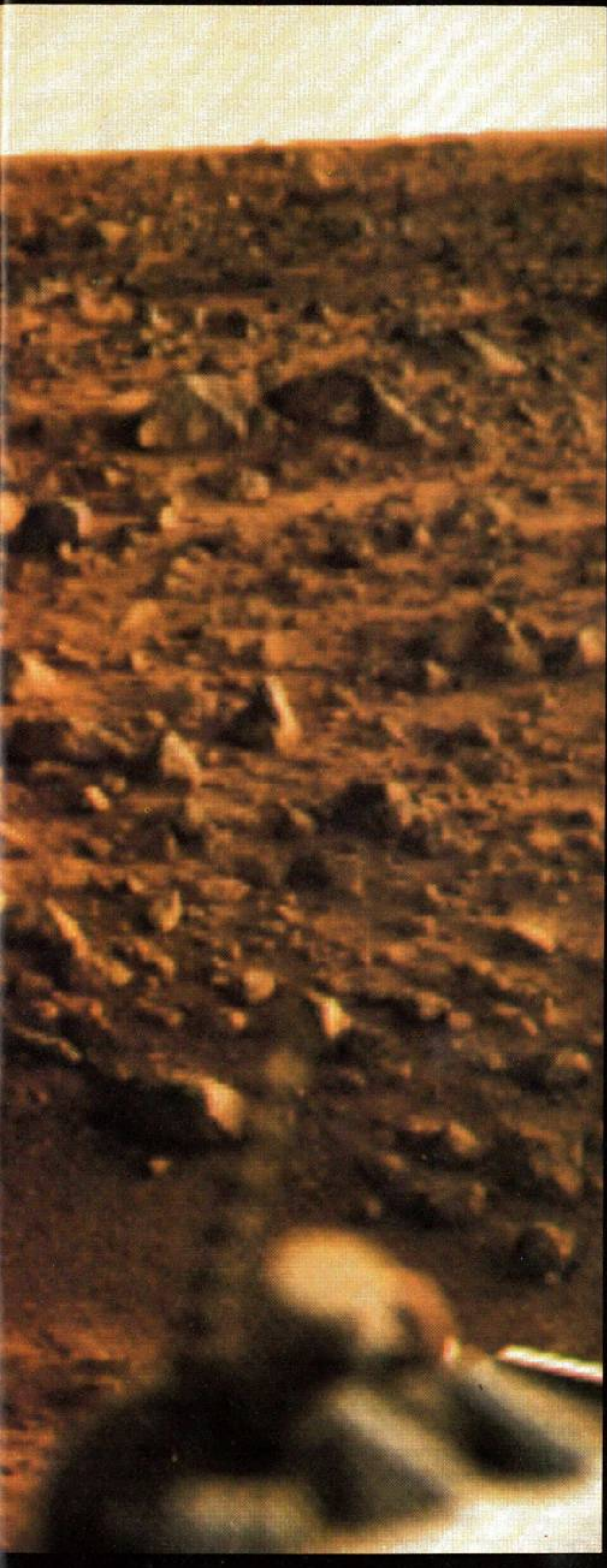
VIKING ON MARS:



EXCITING RESULTS

by William K. Hartmann



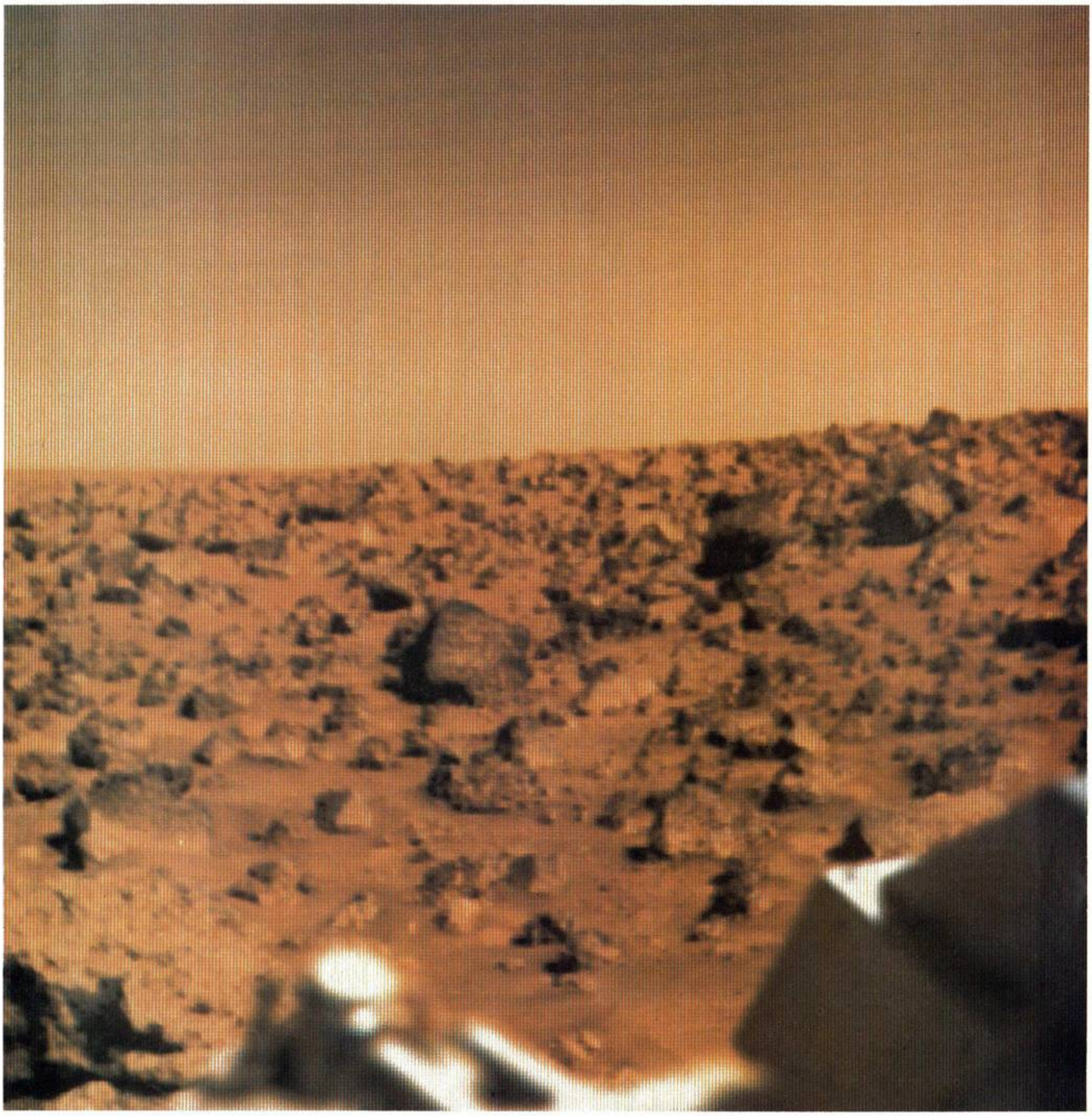
The first two Viking landers revealed rocky Martian landscapes within minutes of arrival. Nevertheless, it has taken months of careful analysis to recognize more subtle characteristics of Mars. Early measurements have now been processed, and new and continuing measurements are expected from both landers and both orbiters for perhaps as long as two more years. Martian characteristics now emerging from the data include the general climate, soil and rock properties, atmospheric properties, the nature of the ancient climate, and the search for life. Scientists looking at results of the experiments — especially the biology — are puzzled to the point of having trouble knowing, even roughly, what is happening on Mars.

Other experiments show readily comprehensible results. Mars is, indeed, chilly. Evening temperatures fall to -100 degrees Fahrenheit. Results of straightforward measurements from the landers show Mars to be a cold, dry world with sparse air. The atmosphere has more dust, and hence more opacity and effect on surface radiation than expected. Most of the reddish light of the sky is sunlight reflected off red airborne dust, rather than scattered off air molecules in the Rayleigh scattering process that produces Earth's blue skies. Temperatures are surprisingly repetitive, day to day, during the summer conditions in Chryse and Utopia (the Viking 1 and 2 landing sites).

While air temperatures, winds and pressures are measured by the landers, the soil temperatures come from the orbiters' infrared sensors. The range of soil temperatures at the top of the 60,000 foot volcano Arsia Mons is unusually high — possibly indicating a different type of soil there, as compared with typical Martian deserts.

More provocative are the temperatures of materials in the Martian polar caps. The caps formed in winter are broad white deposits of carbon dioxide (CO_2) frost, reaching down to middle latitudes and easily seen from Earth. By Martian spring, these shrink back, with carbon dioxide gas presumably subliming into the atmosphere. (Meanwhile at the

About 15 minutes before sunset, the Viking 1 lander took this view facing southwest. At that time, the sun was three or four degrees high and to the right of this picture. Low lighting accentuates ground features, particularly a depression (just above the lander's leg support) which may be an ancient crater. Rocks just beyond the rim of the depression are about one foot (30 centimeters) in diameter. Note that shadows are diffuse due to sunlight scattered in Mars' atmosphere. NASA photograph.

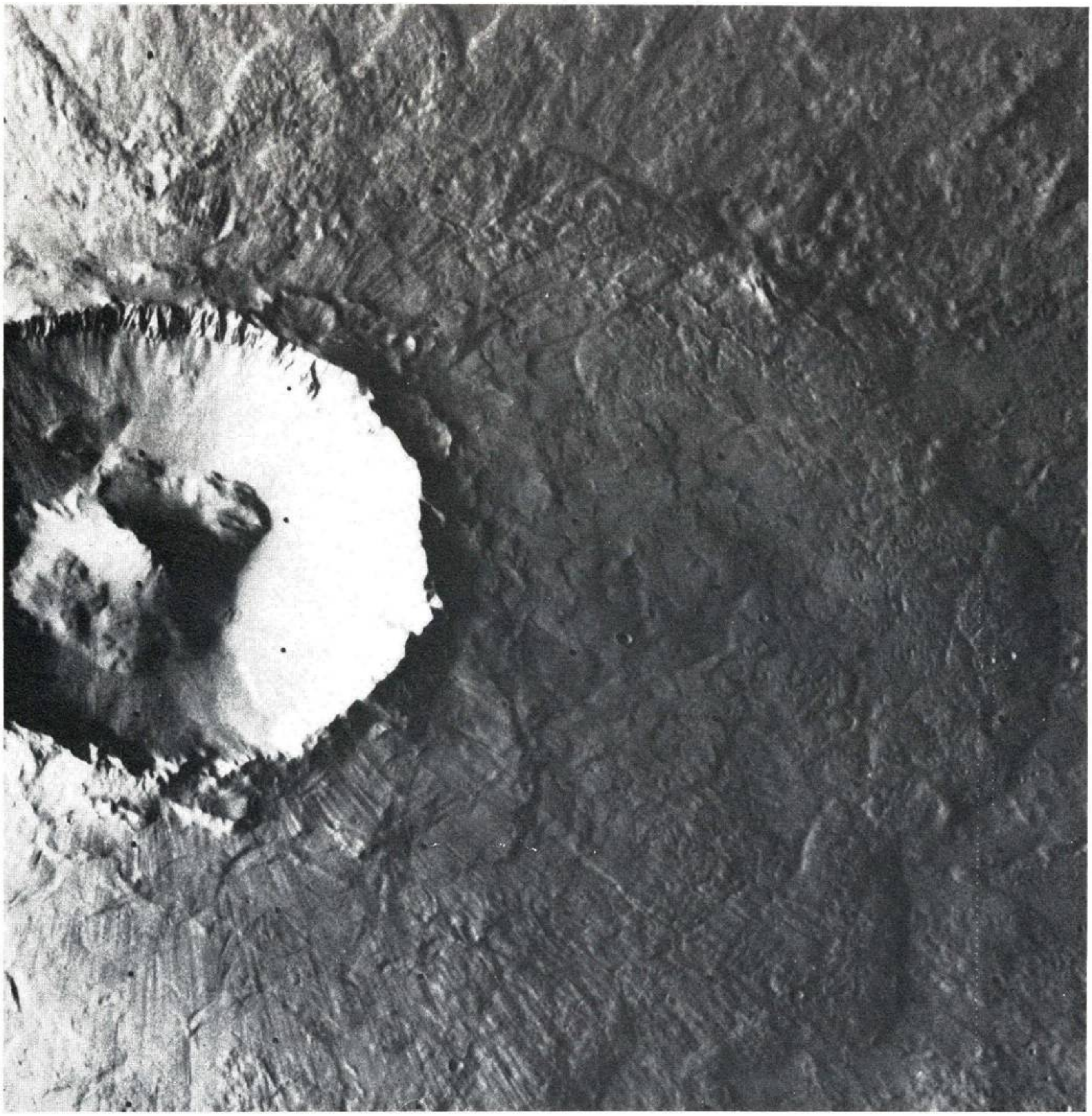


From the Viking 2 lander, this view (looking south) shows a nearly level plain strewn with rocks as large as three feet (one meter) across. Many of the rocks are dark gray and porous, looking like some of Earth's volcanic rocks, while others — such as one at the lower left — are coarse grained, and presumably not of the same origin. Between the rocks, the surface is covered with a dusty or sandy material that piles into small drifts. NASA photograph.

other pole, which is experiencing autumn, CO_2 condenses and expands that cap.) By summer, the small, permanent residual cap that remains is barely visible from Earth.

Viking data shows that the residual summer cap is too warm to be frozen carbon dioxide, or even a carbon dixoide/water mixture. Viking scientists have therefore concluded that each residual cap must be a deposit of relatively pure frozen water — a conclusion only suspected from earlier Mariner 9 data gathered in 1972. No one knows how deep the ice is, but it certainly represents a substantial reservoir of permanently trapped water, unable to circulate under current Martian conditions. These caps may contain up to 10,000 times as much water as the current Martian atmosphere, vividly confirming that in spite of its dry air and soil Mars has water that *could* be tapped if climatic conditions ever were milder.

Both Viking landers find that the air pressure is decreasing from day to day. This phenomenon is related to the polar conditions: Viking landed during northern summer and southern winter, as the northern cap remained static and the southern cap grew. Carbon dioxide was thus disappearing from the air and freezing, perhaps in a CO_2 snowfall,



The Martian crater Arandas is quite different from lunar craters: The conical central peak and sharply defined rim in this 15 mile (25 kilometer) diameter crater are not unusual, but the flow pattern of the ejected material around the crater is very unlike lunar craters. Rather than being blasted away from the crater, material seems to have flowed across the surface. The pattern is similar to experimental craters made in water-logged ground. NASA photograph.

onto the southern cap. This left Mars with less air, and therefore lower air pressure. No such behavior happens on Earth, since no major component of Earth's air (such as nitrogen or oxygen) can freeze at terrestrial temperatures (even those in the Antarctic). Fortunately for life on Earth, Earth's air pressure stays fairly constant (around 1,000 millibars) except for fluctuations due to weather systems.

Viking soil studies confirm another reservoir of trapped water on Mars. At the Viking 1 site, soil samples scooped from within a few inches of the surface were heated in the molecular analysis experiment. At temperatures of around 660 to 930 degrees Fahrenheit (350 to 500 degrees Centigrade), approximately one percent of the sample weight was released as water that was undoubtedly chemically bound in a hydrated mineral — perhaps one of the iron oxide minerals that gives the soil its red color. This observation confirms conclusions of Cornell astronomers who observed spectroscopic evidence that Mars soil contained about one percent water chemically bound. It is important to note, however, that the soil is not moist, but dry; the water is locked, molecule by molecule, into the crystal structure of the minerals. Thus, future Martian explorers should be able to acquire water on arid Mars

Martian Climate Data

Air temperature range (Viking 1)	-123°F to -24°F
Air temperature range (Viking 2)	-115°F to -20°F
Maximum soil temperatures (Vikings 1 & 2)	near freezing
Soil temperatures at summit of Arsia Mons volcano	-207°F to +27°F
Temperature of dark soil around north polar cap (summer)	-36°F to -27°F
Temperature of frost at north polar cap (summer)	-90°F to -81°F
Temperature of frost at south polar cap (winter)	-207°F
Winds (Vikings 1 & 2)	usually less than 10 m.p.h. with gusts to 30+ m.p.h.
Air pressure (Vikings 1 & 2)	7 millibars, decreasing

by heating large volumes of soil to a few hundred degrees in specially designed processors. More readily accessible water may exist if, as many analysts believe, there is more water many feet below the surface in icy layers called permafrost.

Vistas of scattered rocks, sand dunes, and distant low hills that may be crater rims, form the now-familiar Martian landscape. We must remember that, by design and to insure safe landings, Vikings 1 and 2 landed in some of the dullest parts of Mars. (After all, it's better to have measurements of dull, flat places than no measurements at all!) Elsewhere, however, orbital reconnaissance shows vistas of immense canyons, fresh looking lava flows, dune fields, polar ice, and dry riverbeds still unseen from ground level.

Continuing analysis of Viking 1 and 2 landscapes, soil and rocks is yielding interesting information. For instance, a Viking 1 result, not discovered until Aug. 3, 1976, is that the Mars soil is so powdery — at least on one side of the lander — that one of the footpads buried itself at landing! Pictures of pads 1 and 2 showed that they came to rest on a relatively firm surface, scattering only bits of soil, while pad 3 sank in, either due to harder impact or a pocket of softer soil. In general, this soil seems to have the properties of the lunar surface's soil, which in turn resembles the properties of flour or mortar cement. There is some suspicion that Viking 1 may have straddled the boundary between a rock-firm layer and a layer of loose, windblown dust.

Martian Atmosphere

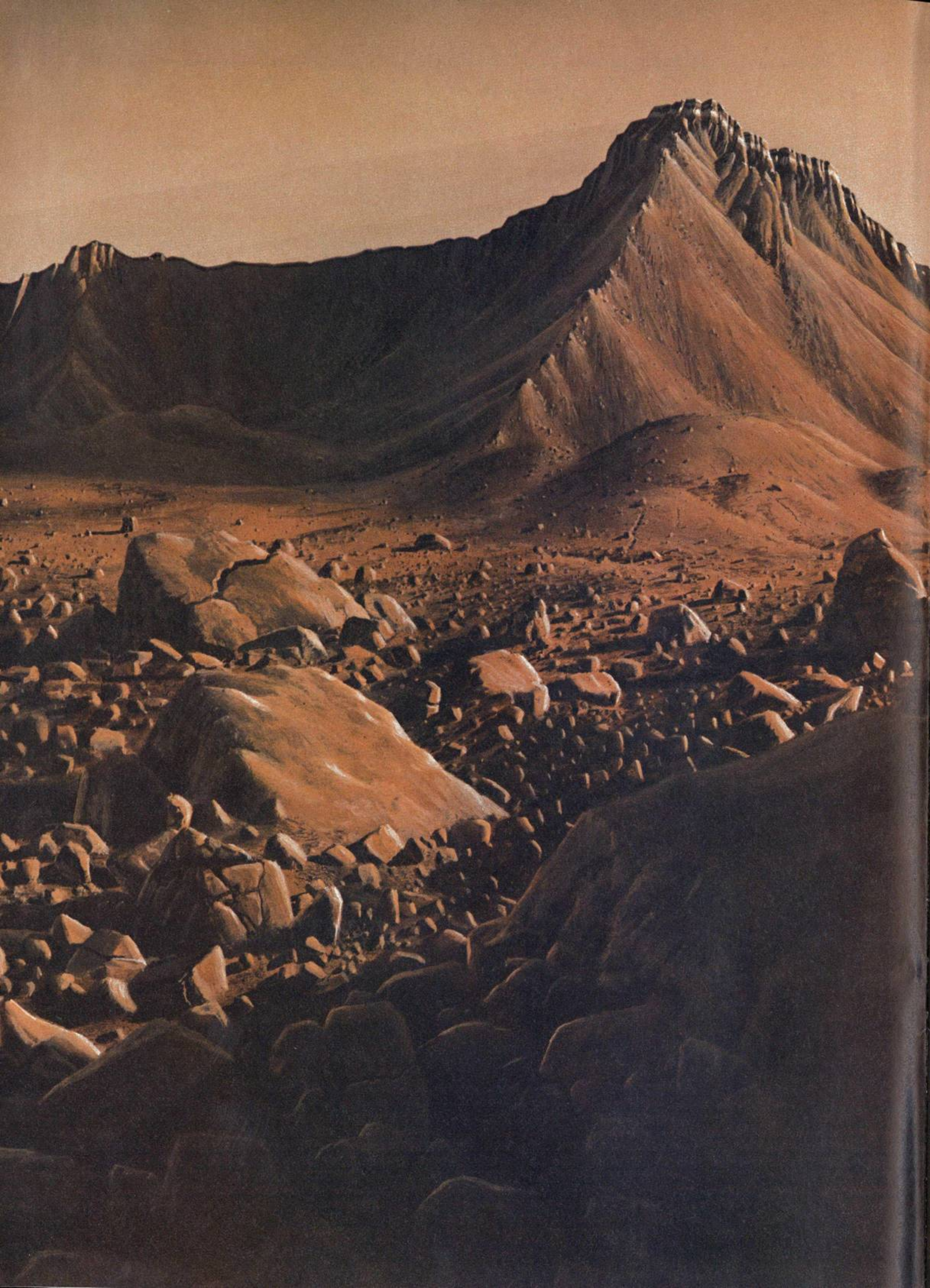
Element	Percentage
CO_2 (Carbon dioxide)	95%
N_2 (Nitrogen)	2.7
Ar (Argon)	1.6
O_2 (Oxygen)	0.15
CO (Carbon monoxide)	trace
H_2O (Water vapor)	trace (varies)
Kr (Krypton)	trace
Xe (Xenon)	small trace

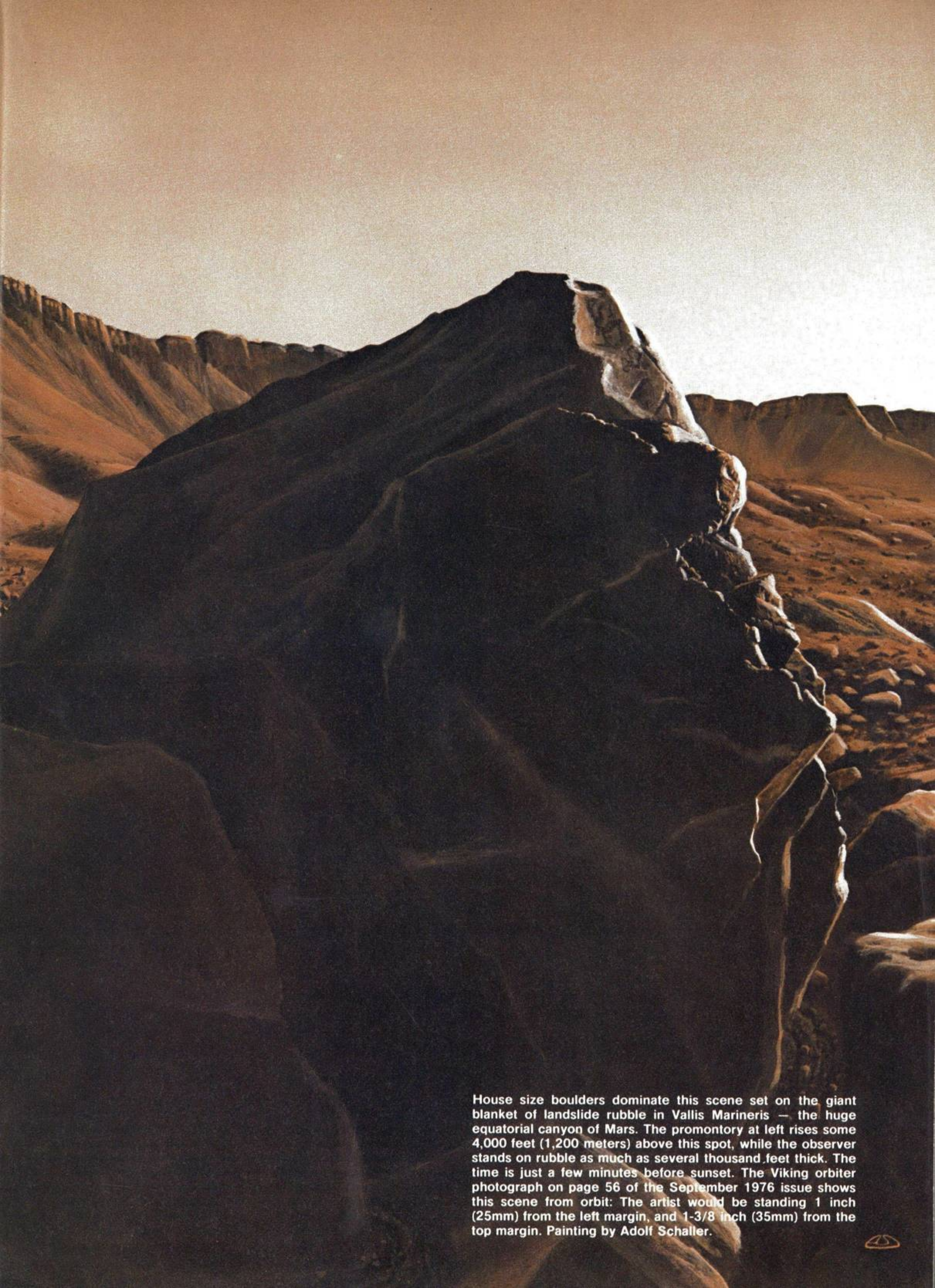
Photos of rocks from Viking 2 also tell an interesting tale. The first picture clearly showed a vesicular, or bubbly, texture in the nearest rocks. Such texture is characteristic of basaltic lava that erupts and cools near the top of lava flows. Near the top of a flow, the gases dissolved in molten lava expand and form bubbles that survive "frozen" when the rock cools. Lavas that never reach the surface (more properly called magmas) are under pressure from the weight of overlying rock, so no bubbles form. Thus, scientists strongly suspect that at least some of the rocks seen in Viking 1 and 2 photos were indeed lavas formed in flows on Mars' surface. In addition, certain lava-sheetlike features seen in orbiter photos of other Martian plains support the lava flow interpretation.

The direct measurements of Martian soil composition (which resembles basaltic lavas on Earth and the moon) further confirm the presence of lavas. Basaltic lavas are the types of lava that erupt in lunar mare plains and in many terrestrial volcanos (such as those in Hawaii). They are produced in hot, partly melted regions of the planets' upper mantle, where radioactive heat sources, or currents of heated material from deeper in the planet, may cause rocks to melt.

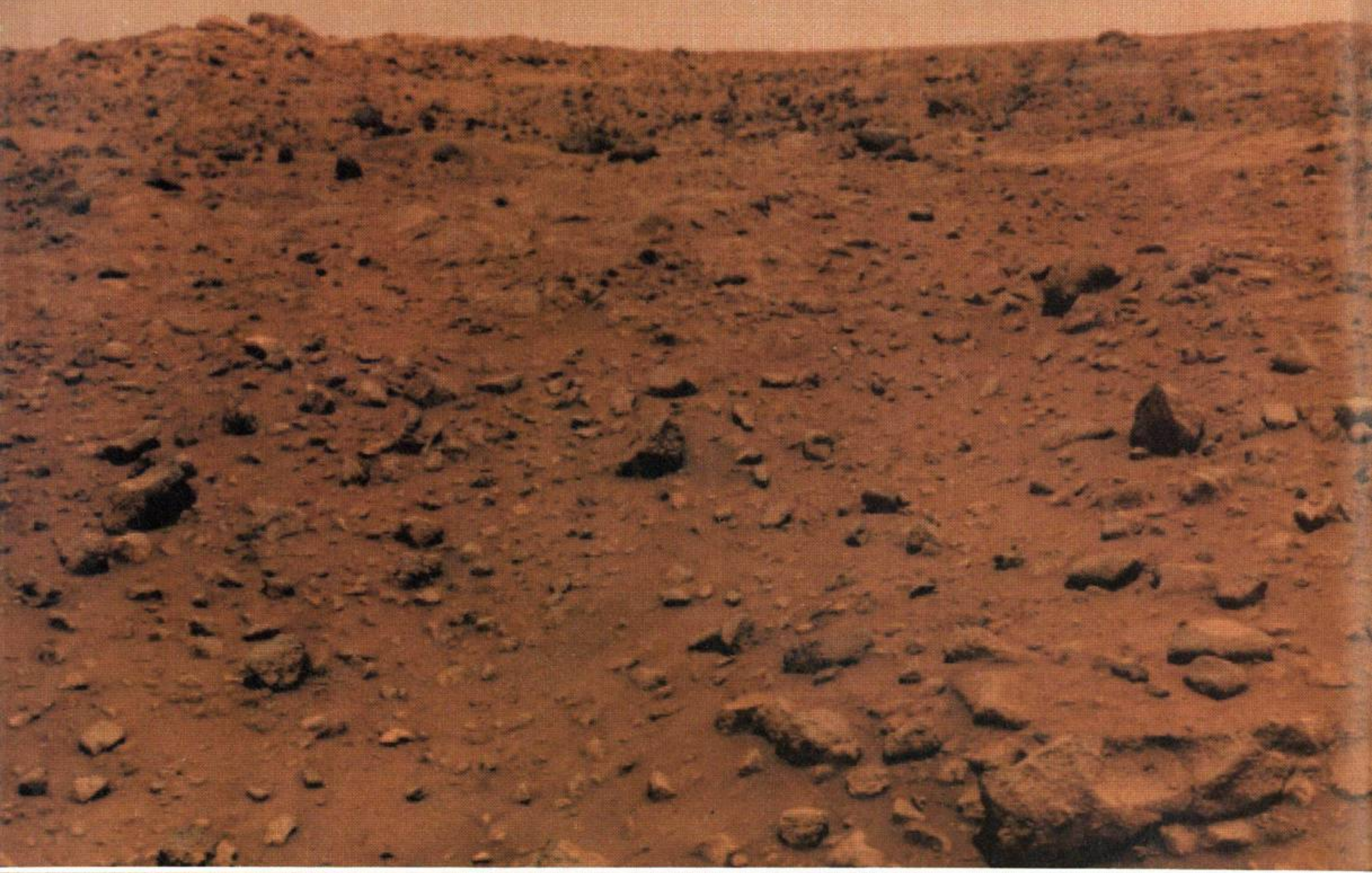
In the most important elements (such as silicon, iron and calcium), the Martian rocks are similar to lunar and terrestrial basalts. As with other rocks so far known from planetary exploration, they seem to have been modified from the meteoritic composition that may represent "primitive" material

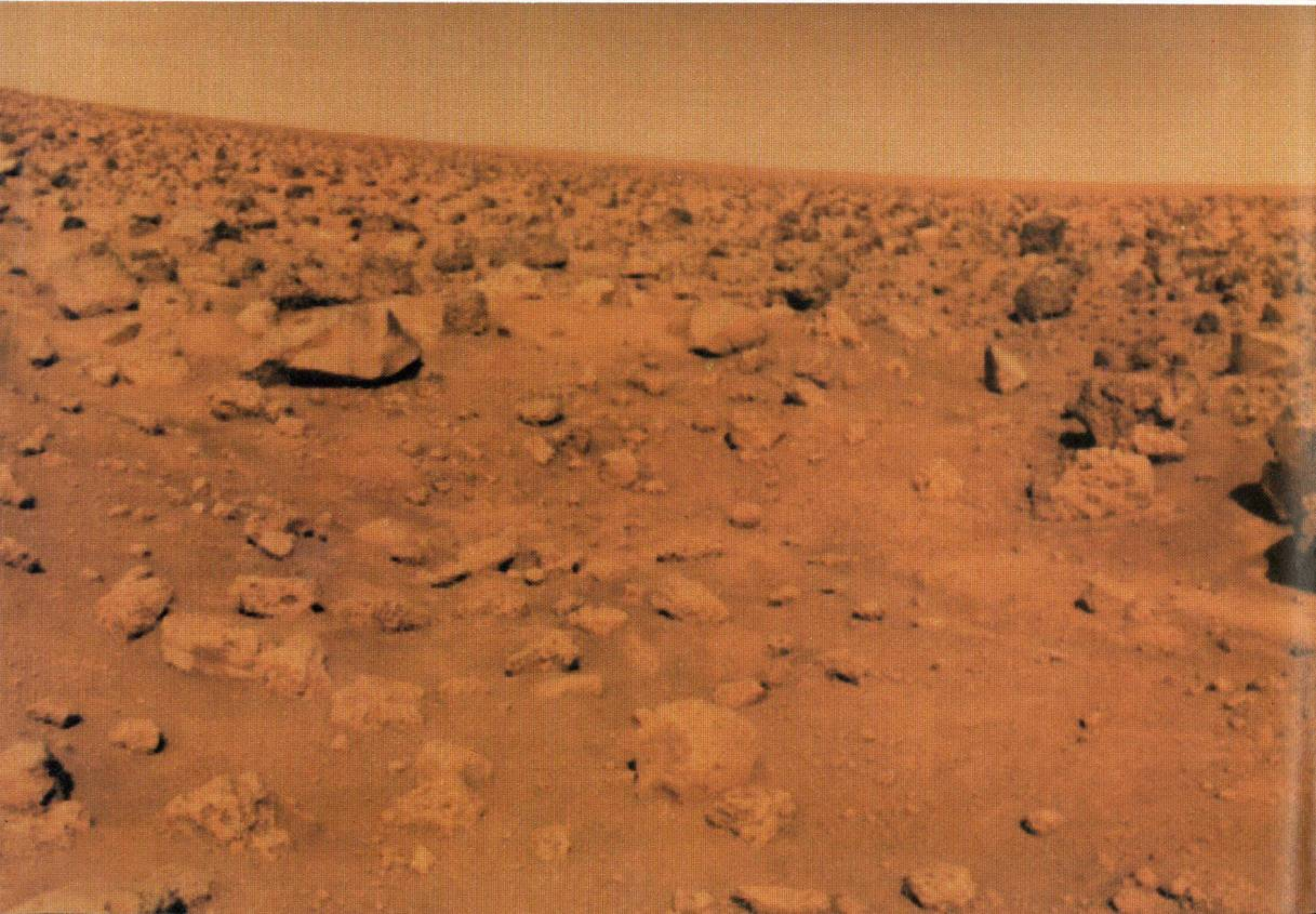
The "Grand Canyon" of Mars (called Vallis Marineris) lies a few degrees south of Mars' equator and runs some 3,100 miles (5,000 kilometers) east to west. This image — a composite of 15 photographs from the Viking 1 orbiter — covers an area over twice the size of the state of Alaska. Color pictures are taken to search for possible differences in mineral composition in the surface. One of the photographs that makes up this image appeared on page 19 of the November 1976 issue. NASA photograph.

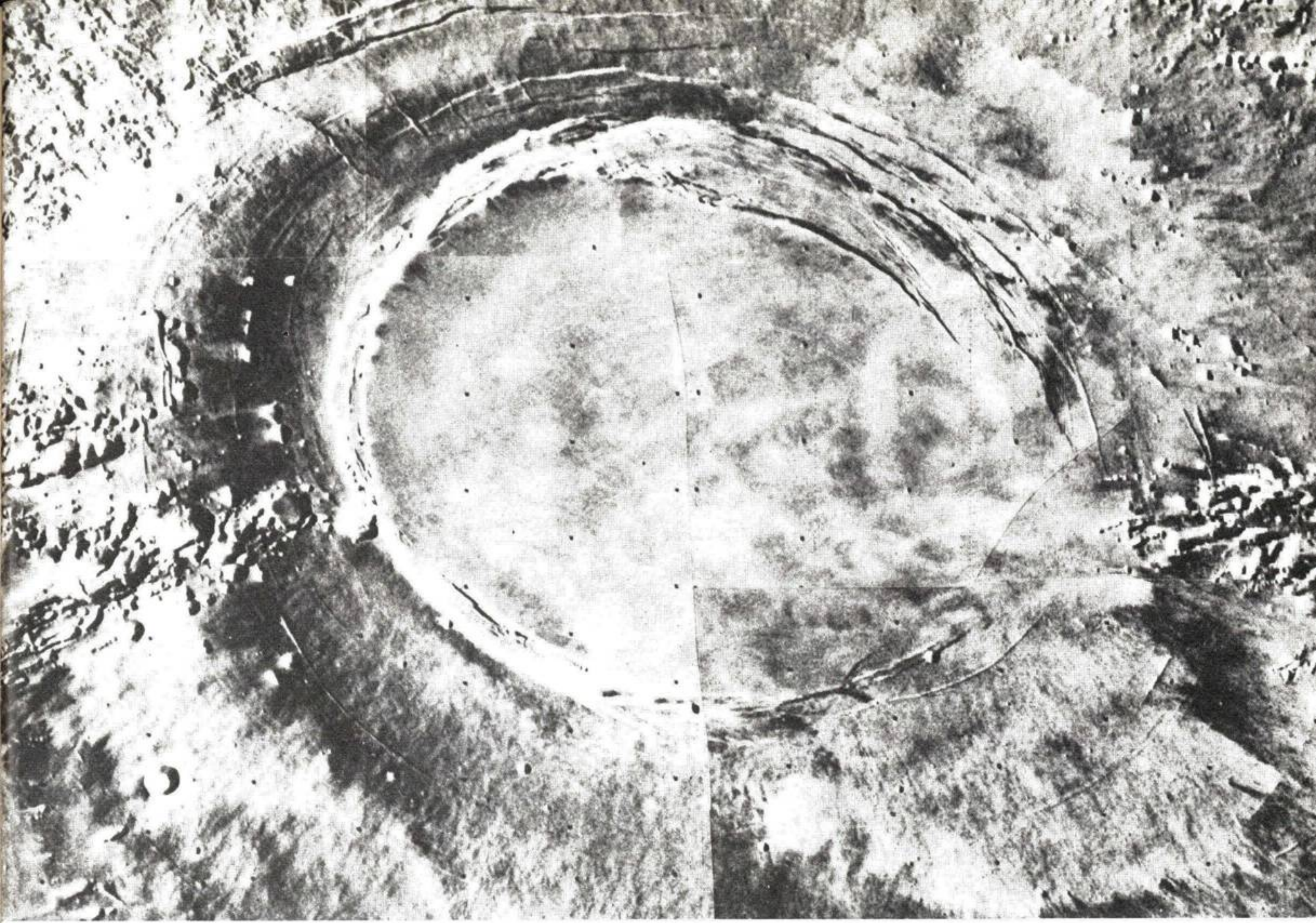




House size boulders dominate this scene set on the giant blanket of landslide rubble in Vallis Marineris — the huge equatorial canyon of Mars. The promontory at left rises some 4,000 feet (1,200 meters) above this spot, while the observer stands on rubble as much as several thousand feet thick. The time is just a few minutes before sunset. The Viking orbiter photograph on page 56 of the September 1976 issue shows this scene from orbit: The artist would be standing 1 inch (25mm) from the left margin, and 1-3/8 inch (35mm) from the top margin. Painting by Adolf Schaller.







Left: Scenes from the Viking 1 lander (above) and Viking 2 lander are strikingly similar — both are rock covered plains — but, at the same time, dissimilar in the types of rocks seen. The variation in color is due almost entirely to the pictures being taken under differing lighting conditions: the lander 1 scene is backlit; the lander 2 scene is lit "over the shoulder" of the camera. Above: The summit of the giant volcano Arsia Mons, also known as South Spot, is a collapsed caldera about 75 miles (120 kilometers) across. Outside the caldera, lava flow features are visible. NASA photographs.

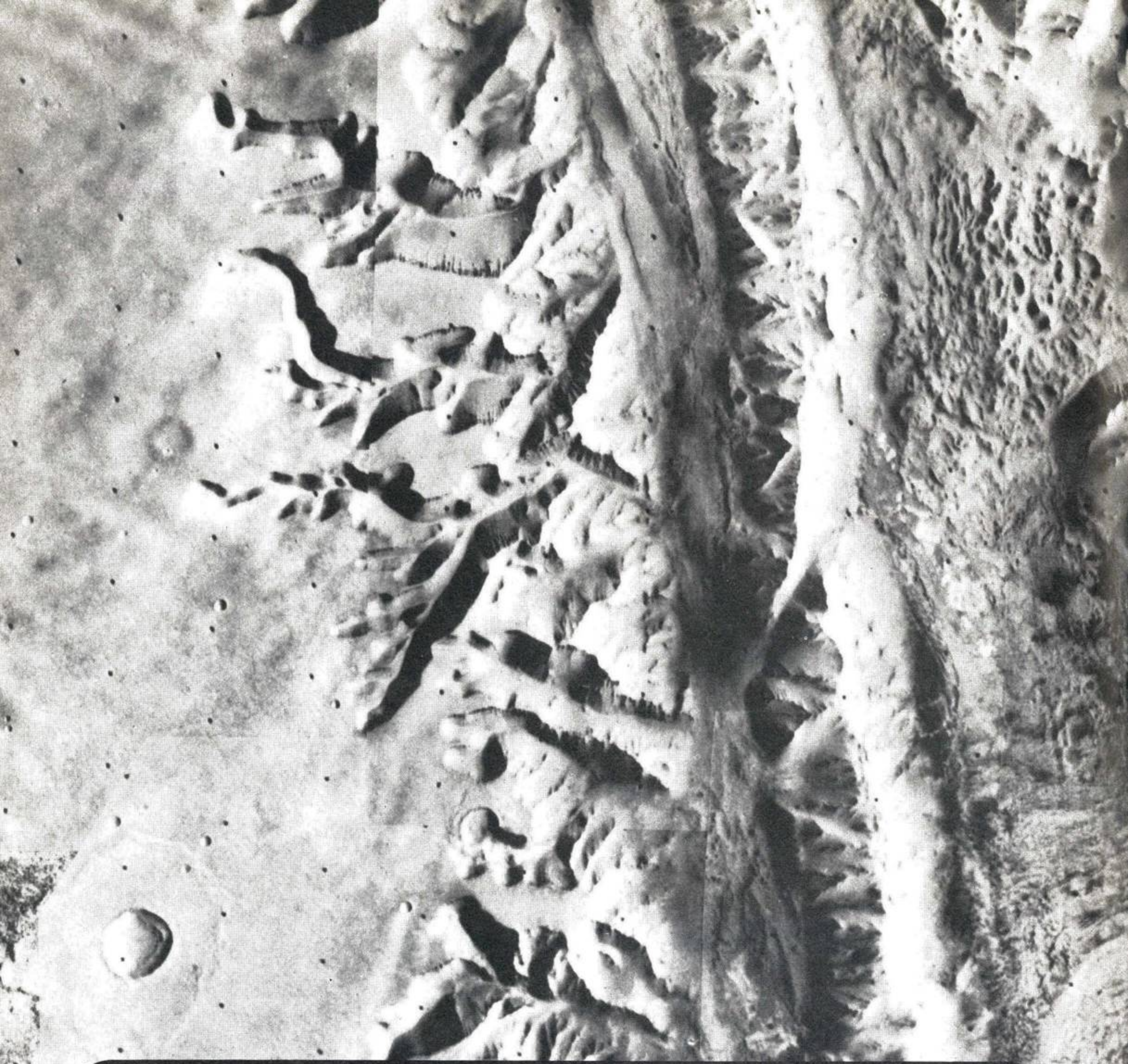
from which the ancient solar system formed. Such modification would be expected from the melting and volcanic processes in planets' interiors. Their high sulfur content (relative to other solar system bodies) may be due to sulfates leached from deeper soils and concentrated at the surface when moisture occasionally sublimes into the Martian air. The measured compositions of Mars soil are markedly unlike many sedimentary rocks — or remains of living organisms (which may be about 45 percent carbon, 40 percent oxygen, and a few percent nitrogen and hydrogen).

The *chemical* indications that the Martian soil derives from basaltlike rocks agree with the general *appearance* of the rocks. Those not coated with red iron oxide stains are dark, basaltlike gray, rather than the whiter tones of quartz-rich granitic rocks common on Earth's continents. The soils of Mars are probably derived by erosion of old lava flows, and mixed to some degree of uniformity by Martian winds. The absence of granitic rocks on Mars, if it holds for the whole planet, may mean that Mars' crust has not evolved geologically as much as Earth's. This tentative conclusion agrees with indications in orbiter photos that Mars lacks the mountains, fractures and continental "plates" typical of Earth.

This raises the question of evolution of the entire planet, and the thin air of Mars contains many of the most important clues. Viking scientists have found new evidence to support the idea that the thin Mars air is the last remnant of a once impressive atmosphere.

Their reasoning is somewhat complicated. Beginning with measurements of the composition of the present atmosphere (as observed by both landers and the entry-science data at high, middle and low altitudes), the data combines to allow interpretation of the early atmospheric history of the planet. In Mars' low gravity, light gases can escape from the planet at a faster rate than gases with high mass molecules. The escape rates can be calculated, so that if we know the present abundances of the molecules, we can extrapolate back into the past to see what the abundances must have been.

The various methods used tend toward the conclusion that there must have been much more gas on Mars in the past than there is now. Whereas Mars' present atmospheric pressure is around 7 millibars

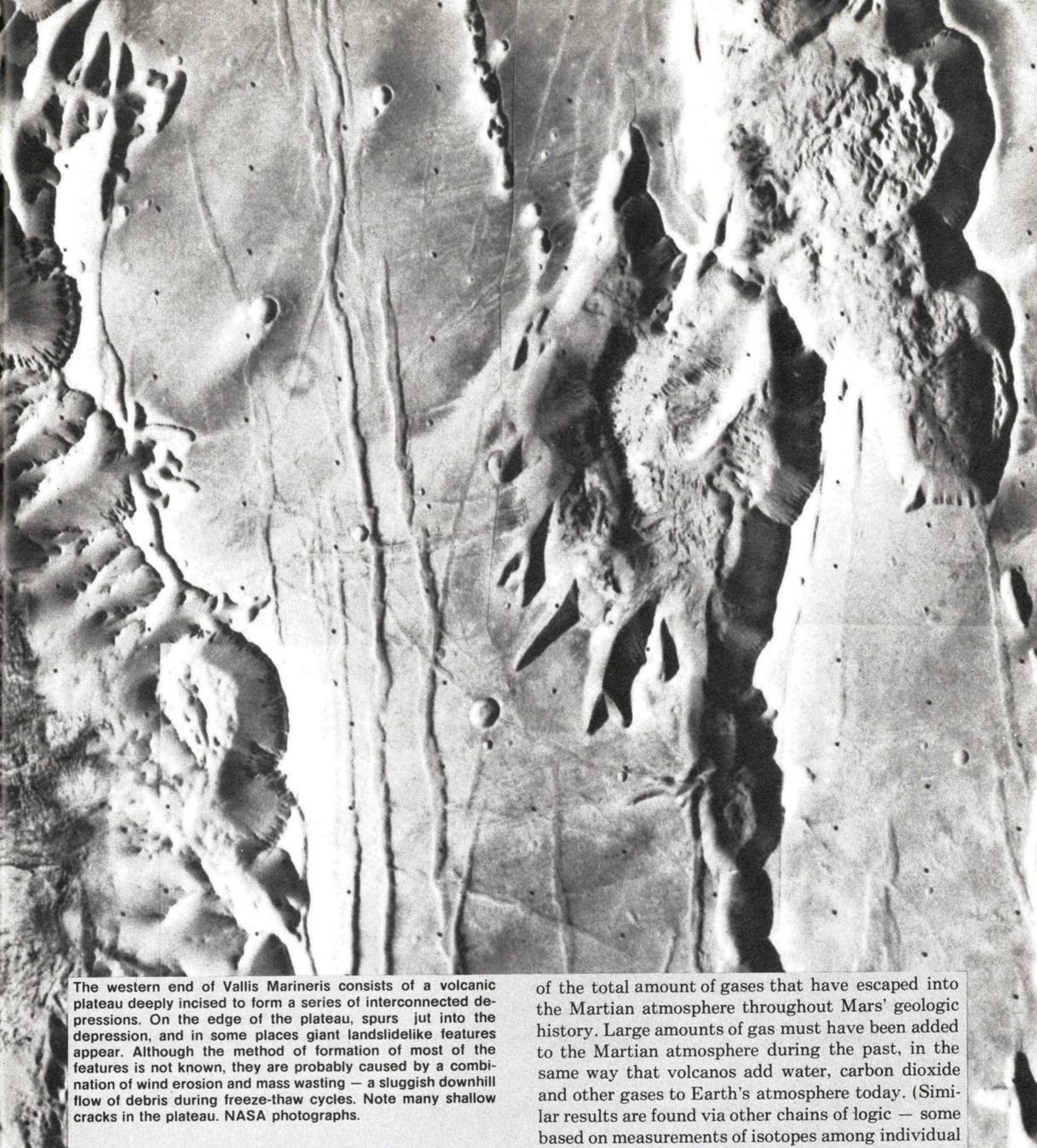


Elements Found in Solar System Objects

	Mars soils (Vikings 1 & 2)	Meteorites (average)	Moon mare basalts	Earth basalts	Earth granites
Silicon	15-20%	16%	23%	23%	33%
Iron	14	29	11	9	2
Calcium	3-8	1	8	8	2
Aluminum	2-7	1	8	8	8
Sulfur	2-5	2	0.2	0.3	0.3
Titanium	0-1	0.13	2	1	0.2

(compared with Earth's 1,000 millibars), estimates suggest Martian pressures in ancient times lay between 10 and 1,000 millibars. Earth's surface pressure never changed much by this escape process, because Earth's high gravity keeps most of its gases from escaping.

One line of reasoning is that of Viking scientist Michael McElroy, who starts with a well-known theoretical result: Argon, a heavy element, stays in the Martian atmosphere and does not escape into space. Also, because argon is chemically inert, it does not combine with rock minerals so that it

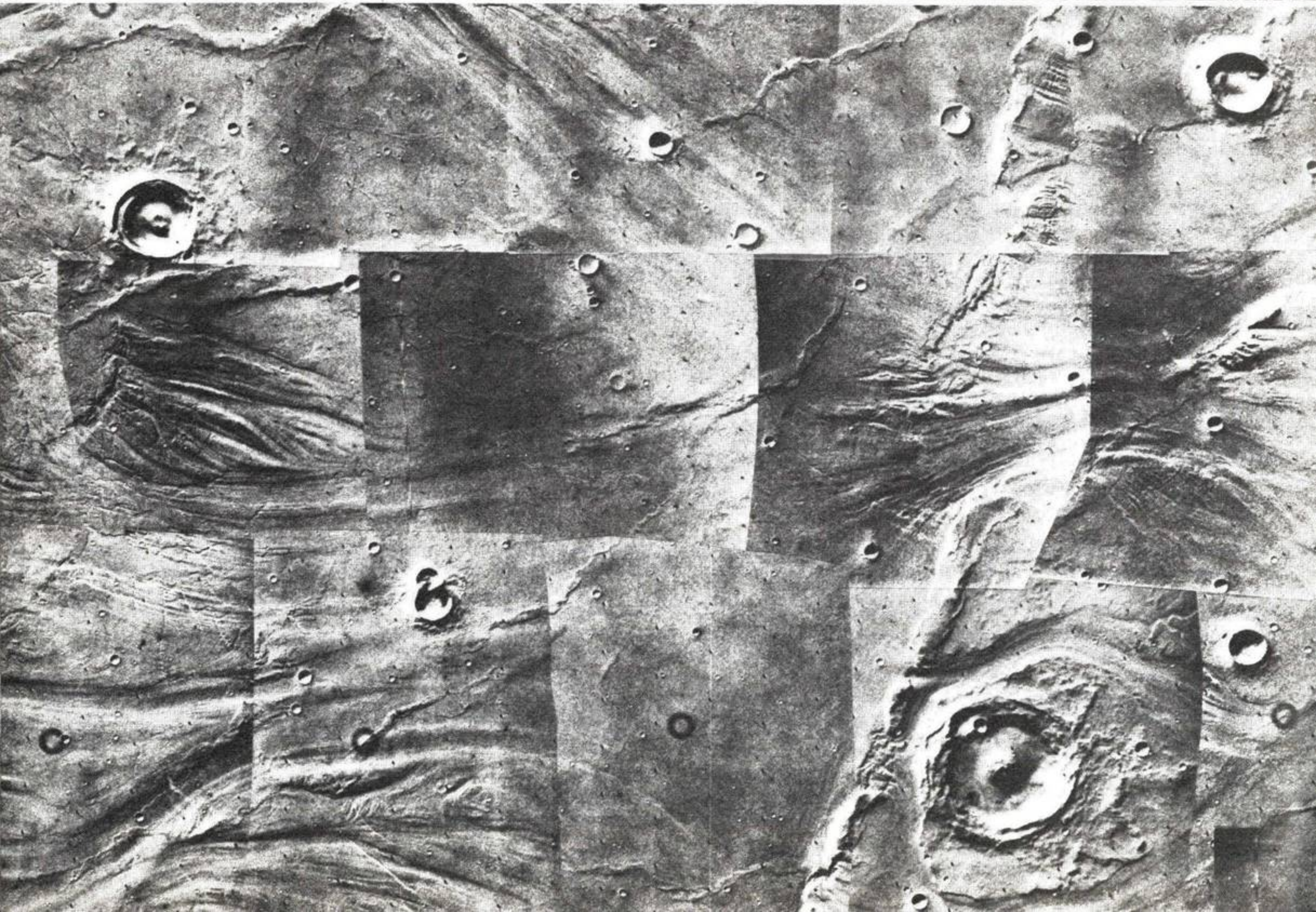


The western end of Vallis Marineris consists of a volcanic plateau deeply incised to form a series of interconnected depressions. On the edge of the plateau, spurs jut into the depression, and in some places giant landslidelike features appear. Although the method of formation of most of the features is not known, they are probably caused by a combination of wind erosion and mass wasting — a sluggish downhill flow of debris during freeze-thaw cycles. Note many shallow cracks in the plateau. NASA photographs.

stays in the air. Volcanism and other processes that allow gas to escape from planets' hot interiors (processes called *degassing*) add argon to the atmosphere. Therefore, argon is an excellent indicator of the total amount of gas that a planet has given off.

McElroy notes that, relative to its total mass, Mars has produced only about 1/25 as much argon as has Earth. He has thus assumed that Mars has degassed about 1/25 as much of *all* gases as Earth has (a fairly safe assumption since volcanic materials contain a fixed mixture of gases), giving an estimate of the total amount of gases that have escaped into the Martian atmosphere throughout Mars' geologic history. Large amounts of gas must have been added to the Martian atmosphere during the past, in the same way that volcanos add water, carbon dioxide and other gases to Earth's atmosphere today. (Similar results are found via other chains of logic — some based on measurements of isotopes among individual gases found on Mars today.)

So, if much of the Martian volcanism occurred in early times, the estimates suggest that Mars once had a much denser atmosphere containing hydrogen, oxygen and nitrogen, after the volcanos erupted but before the gases escaped. Nitrogen, alone, may have been abundant enough to account for surface pressures up to 50 millibars, not to mention additional pressure from other gases. In other words, it is *conceivable* that Mars, in the first billion years of its existence, had a roughly Earthlike atmosphere.



But where did the gases go? McElroy, an expert in atmospheric chemistry, has studied ways gases can escape a planet. Both oxygen and nitrogen form ions (charged atoms and molecules) in the high atmosphere. These ions, O_2+ and N_2+, combine with electrons and break into individual atoms, O and N, moving at high speeds (5 to 6km per second, or 12,000 m.p.h.). Since the escape velocity of Mars is less than this, these atoms would escape into space. When the same process occurs on Earth (producing the same speeds), the speed is insufficient for escape from Earth's greater gravity. So, most of the nitrogen has escaped from Mars, but not from Earth. This explains the high nitrogen content of Earth's atmosphere, and the theory checks. Another check is that estimates of the nitrogen escape rate show that the pressure would decline from the high ancient values to a value of about 0.35 millibars — the value actually found today.

What about the missing oxygen? Perhaps there are still unknown escape mechanisms that allowed all the ancient oxygen to leak into space. But it could be that the old idea of long-dead Martian seas is not just fantasy. Many scientists, including McElroy, have considered the possibility that vast amounts of oxygen are locked away as water and carbon dioxide that has frozen out of the atmosphere. Under present conditions, it would be hidden on Mars in the form of ices or water/carbon dioxide mixtures called *clathrates*. In the past, during an episode (or episodes) when the atmosphere was denser, liquid water may have flowed on the surface. Sufficient water and carbon dioxide would have helped the atmosphere attain enough pressure and warmth to allow water to be liquid, although it cannot exist there now.

Top left: A remarkable set of water channels runs into the Chryse basin. Across the width of this scene, the ground drops about two miles (three kilometers). Tributaries and other features — such as flooded craters with breached walls — attest to the presence of large amounts of runoff water. Lower left: Northwest of the original Viking 1 landing site, lava flows (broken by faults and peppered with meteor craters) have been altered by water flow. In places, water was dammed behind ridges before breaking through and cutting watergaps. Above: Shortly after sunset, the Viking 1 lander photographed a Martian sunset. The horizon is seen in silhouette; near the sunset point the sky is tinged blue. Farther away, the sky has a redder hue. The blue tones of sunset contrast vividly with daytime Martian reds and oranges. NASA photographs.

All this ties in beautifully with the evidence — already mentioned — for large amounts of water frozen in the permanent polar caps, frozen carbon dioxide in the transient caps, chemically bound water in soil minerals, and possible ice in subsurface permafrost layers. It also ties in beautifully with the Mariner 9 orbital photographic evidence for water flow in now-dry channels that resemble riverbeds. New Viking orbiter photography has dramatically extended this evidence: In some regions, craters and hills have been eroded into streamlined teardrop shapes, apparently by sheet runoff of widespread water.

Orbiter cameras have eliminated most lingering doubts whether the Martian channels were really riverbeds carved by flowing water. Furthermore, the channels are more widespread than had been thought. Many channels have complicated tributary systems, where five or more orders of tributaries-feeding-tributaries can be seen. Tributaries fan out into featureless deserts in some cases, implying that the water did not pour from some single source (such as a volcano or geyser), but fell from a diffuse source. In other words, it may have *rained* onto the surface. Rain on ancient Mars would be a strong confirmation of an atmosphere much denser than the present. The number of craters superimposed on the channels indicate that they are not recent; it may have been a billion years (or more) since the last rain.

Almost all Viking results relate to the famous question: Is there life on Mars? If the above facts were all that had been discovered by the Viking missions, scientists would be more convinced than ever that life has probably evolved on Mars at some time in the past. Laboratory experiments on Earth show that — in an environment with liquid water and gases composed primarily of carbon, hydrogen, oxygen and nitrogen, with energy sources such as solar ultraviolet light — amino acids will form. In other words, biochemists have not created life in the lab, but they have created basic components of life in environments similar to those postulated for ancient Mars and ancient Earth.

When it comes to life on Mars, science fiction writers seem to have gone too far. After looking at Viking pictures, you don't have to go out on a limb to say that the weird leathery Martians, giraffes, the ochre moss, deserted amphitheaters, and coral trees they predicted are probably not there. Of course, the writers had an ulterior motive: Life livens up Martian stories.

But what of the scientific speculations mentioned earlier? According to them, life might have been expected to evolve. After looking at the pictures, scientists who conceded that the planet does not (to use Carl Sagan's memorable understatement) seem to be teeming with large organisms from pole to pole, still thought that microscopic life forms might exist in the soil. Contrary to everyone's hopes, however, the search for Martians seems to have turned into a confusing muddle.

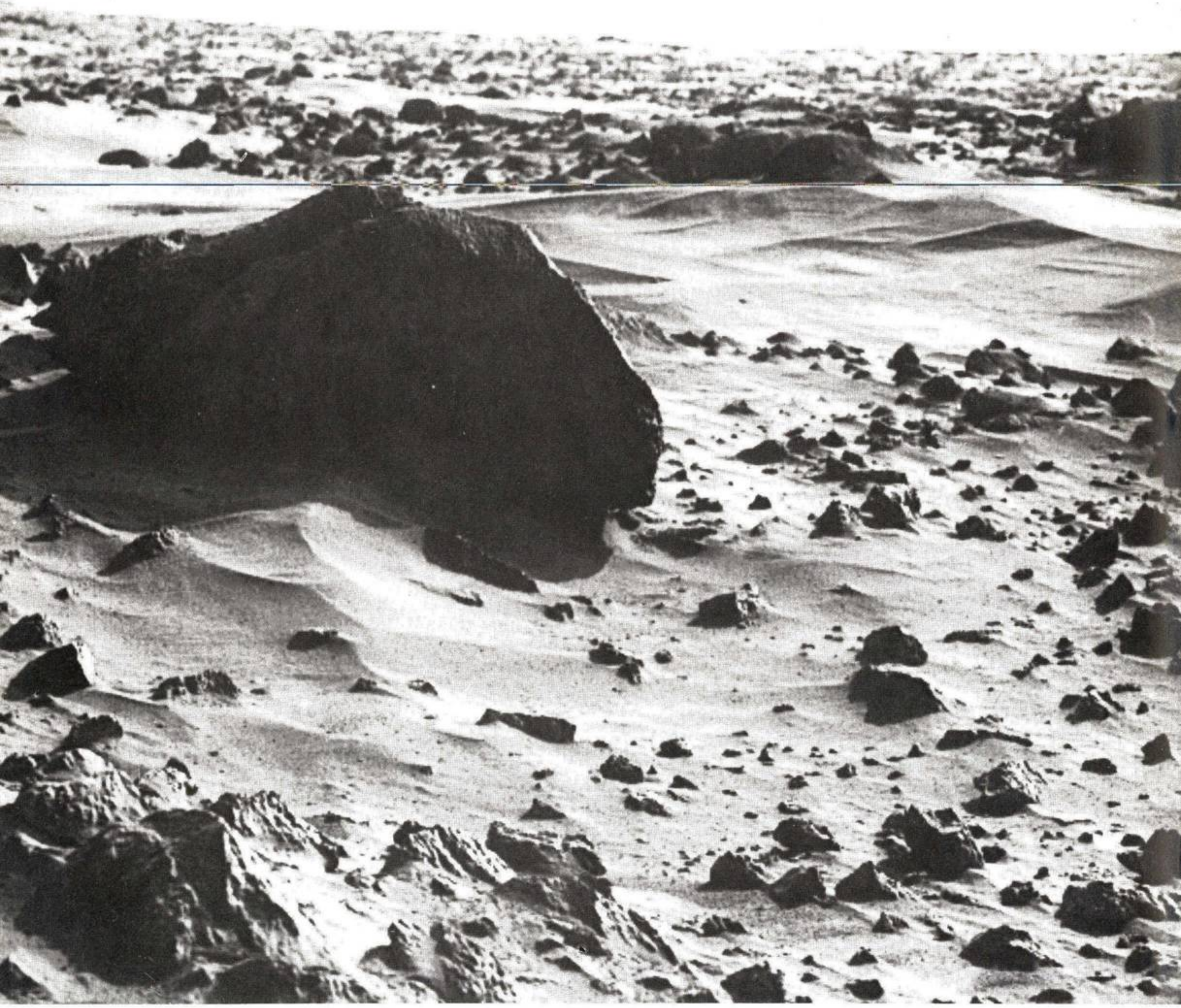
Five experiments, carried on each lander, can be said to participate in the search. The results might be described as two nos and three ambiguous yeses. First, the cameras showed no sign of life at all. Second, a gas chromatograph identified no molecules that we would recognize as living. The most complicated molecules found in the Martian soil were carbon dioxide (molecular weight 44) and water (molecular weight 18). Any of the complex organic molecules found in life forms must be limited to minute traces (less than a few parts per billion) in the Martian soil. This, in itself, seems to rule out life as we know it on Mars in the present or fairly recent past.

But paradoxical surprises came from the other three biology experiments. As explained in more detail in the following article ("Life on Mars: Ambiguous Results"), these experiments search for chemical changes caused by ongoing life processes. One, the pyrolytic release experiment, searches for evidence of photosynthesis or similar processes. Another is the label release experiment, which looks for gases released during organisms' metabolism of nutrients. And finally, the gas exchange experiment looks for gases released as organisms consume nutrients. All three experiments showed positive signs of the activity they were designed to seek, but the signs differed in amount and duration from those found for terrestrial organisms.

Viking biologists thus face a paradox. How can there be life if there are no heavy organic molecules? If there is no life, what is wrong with the three life detectors on each lander, and why has Mars produced no organisms? There are various possible explanations to these questions. The answer to the first question is probably that life can't exist without massive organic molecules, unless we have completely misunderstood the nature of life. As for the life detecting experiments, one theory is that minerals on Mars, being exposed to a different chemical environment than that studied on Earth, may exhibit unexpected chemical reactions in Viking's experimental test chambers. For example, Mars' thin air does not screen ultraviolet sunlight as well as Earth's, and the greater ultraviolet intensity may leave iron oxides in unfamiliar chemical states that could mimic some aspects of life processes in the test chambers.

For this reason, reporters at the Viking press conferences asked about "throwing in the towel" in the search for life. Most Viking scientists, however, are not ready to rule out life. One idea — that the solar ultraviolet light breaks down the organic

The largest rock near lander 1, nicknamed "Big Joe", is covered by a mantle of red dust. The dust cover is evidence that Mars dust storms move substantial amounts of material. The rock is about 26 feet (8 meters) from the lander and is roughly 7 feet (2 meters) long. Its rough texture and dark color suggest that it may be a large fragment of basaltic lava. It may have been dislodged by a crater forming impact within a mile (1.6km) or so of the landing site. NASA photograph.

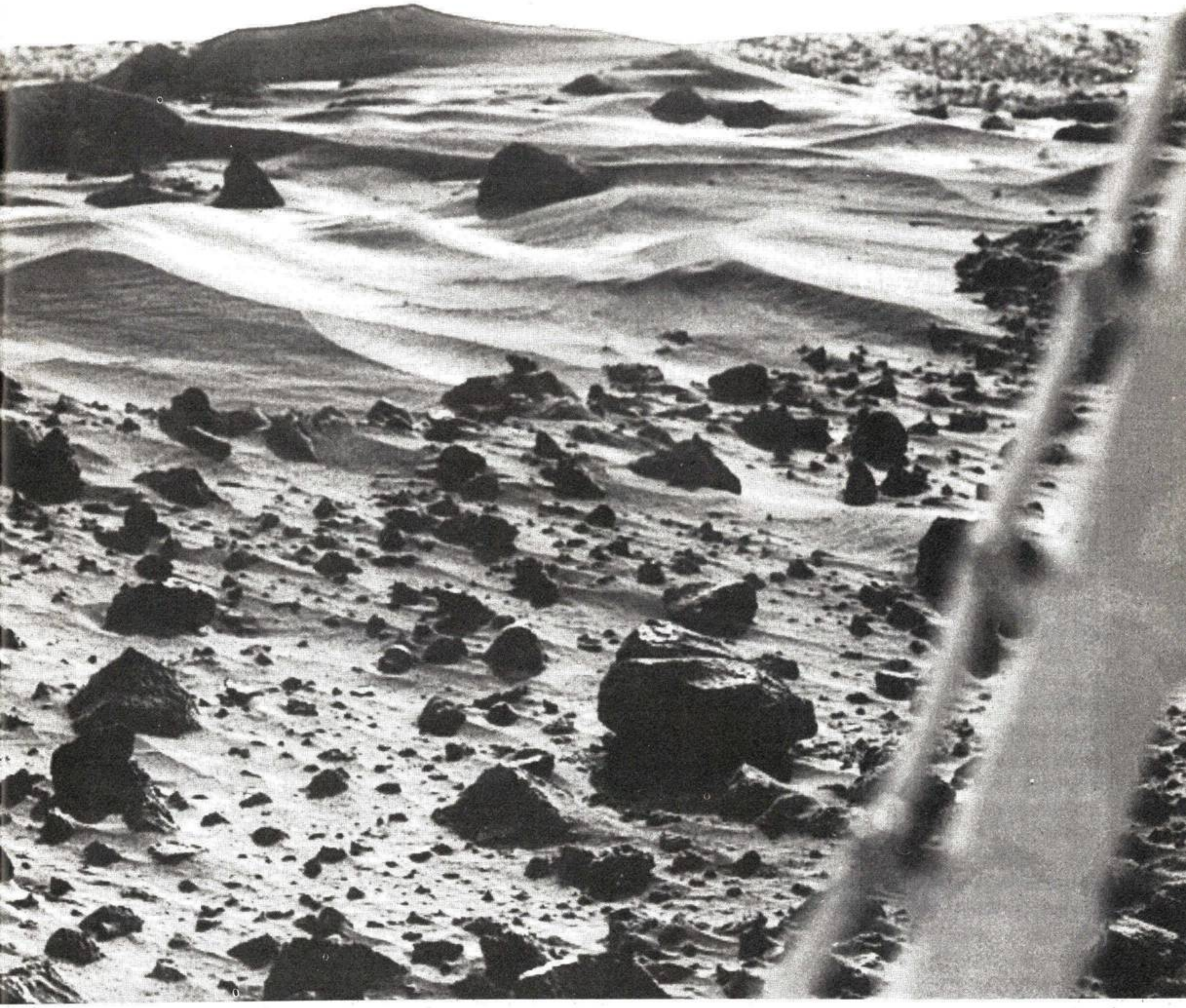


molecules in the surface soil layers, but that primitive life could exist in protected areas under the surface or under rocks — led to successful efforts to push aside a rock and scoop up soil from beneath it. Tests on the protected soil are still incomplete as this is being written.

Another hypothesis is that Mars has no life now, nor had it in the recent past, but that primitive life might have evolved in ancient times when more water was available. The lack of organic molecules today would be explained by saying that, after Mars froze and dried, organic molecules in the soil were broken down as the wind mixed the dust, and solar ultraviolet light irradiated it. If any evidence could be found to support this idea (none has been found yet), exciting research would follow to find out what stages of evolution were reached, and when.

The most negative hypothesis would be that there is no life now and never has been. If that were true, then what of scientific theory? Are years of experiments about the origin of life completely wrong? Is Earth the only place where organic chemical processes formed life? Is life somehow unique to Earth? These ideas seem unlikely. Even meteorites have been found to have extraterrestrial amino acid molecules. A possible explanation of the Martian findings to date is that, while there was water on Mars in the past, it never existed in large, fixed pools long enough for the prebiological or early biological reactions to proceed very far. Biochemists suspect that millions of years were required for a prelife "broth" of organic molecules to form in the early oceans of Earth, where evolution could begin. Furthermore, a billion years were needed to produce the simplest fossil cells, and three billion years more to produce familiar shellfish fossils. For all we know, Martian water might have run in episodes lasting only 1,000 years.

So a possible (not a definite) solution to the Viking biology paradox is that the biology experi-

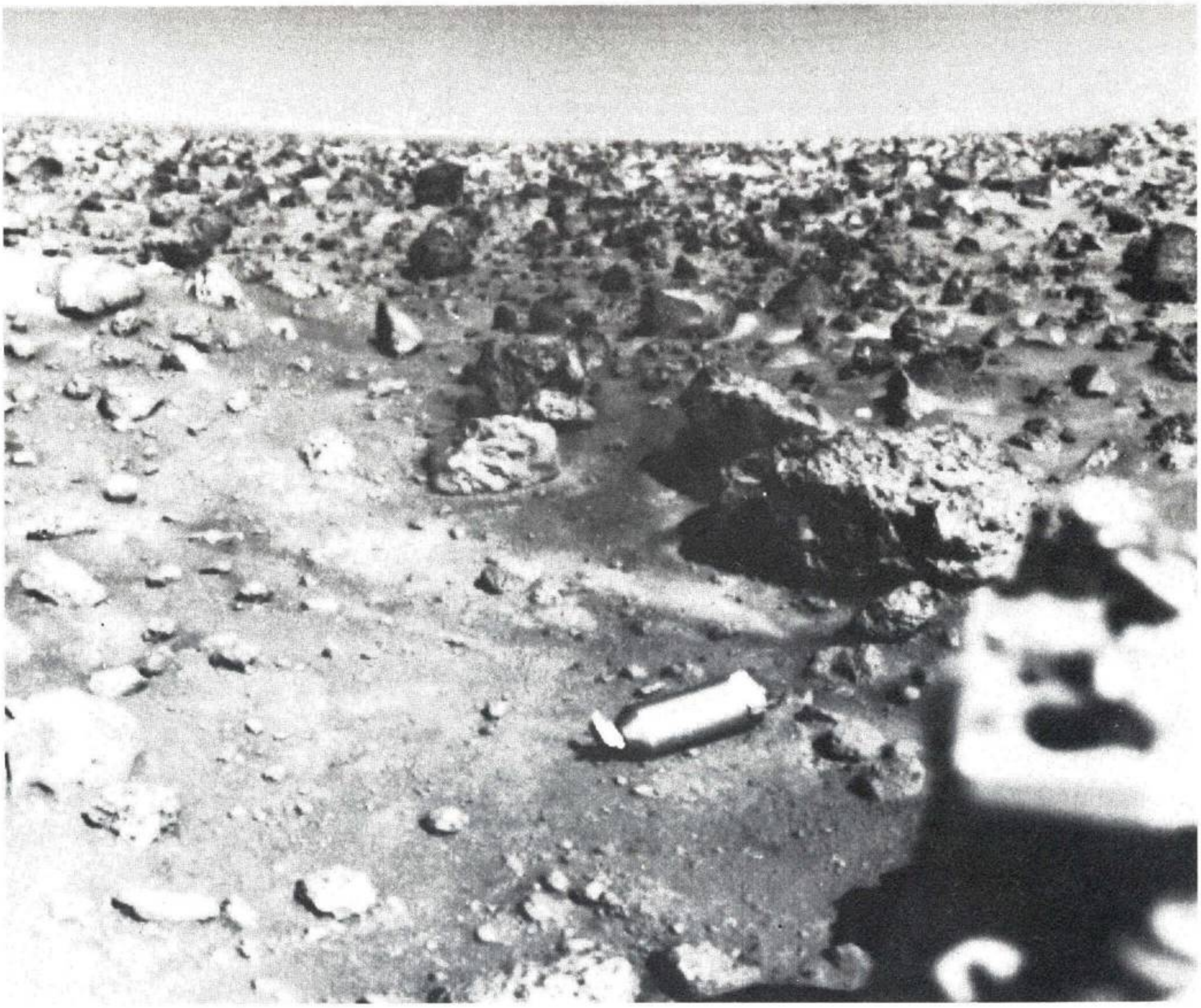


A high resolution black and white view of "Big Joe" and the dune fields near it complements the color photograph on the previous page. Here, dramatic early morning lighting reveals the shapes and textures of the dunes. Sharp dune crests indicate that the general direction of recent wind storms is from upper left to lower right. Big Joe appears to be part of a field of large blocks that has a roughly circular alignment, which may be the rim of an ancient degraded crater. This picture adjoins the one on pages 16 and 17 in the November 1976 issue. NASA photograph.

ments have been misled by unexpected soil chemistry, that there are no organic molecules and no life on Mars now (or in the recent past), or that, while organic chemistry may have led to biological activity in the remote past, there was no water around long enough for advanced life forms to evolve.

What is next? We are still in the early stages of reconnoitering Mars. Viking instruments are expected to stay active for many months or even years. As Mars enters new seasons and new weather patterns occur (perhaps including the great dust storms that usually occur as Mars passes its point closest to the sun), and as soil samples are incubated for longer periods of time, the answers may turn up. Will it turn out that those seasons have changed, those winds blown and clouds scudded across the sky, dust storms raged, rocks rolled down hills, volcanos erupted, and ice fields melted all without any living creature there to witness? Further Viking data should help clarify the problems in our understanding of the evolution of planets. Viking data seems certain to support the idea that Martian history will clarify Earth's history. Mars' crust, with its one major rift canyon (the Valles Marineris), may show the earliest stages of planetary fracturing that produced Earth's continental plates. Mars' violent climatic contrasts — from a running water environment to a cold, dry environment — might shed light on still unexplained major climate changes in Earth's past.

Future return missions to Mars are likely.



The shroud that protected the surface sampler arm during the trip to Mars now lies in the foreground of this lander 2 picture. When it was ejected, it struck the rock at the bottom of the picture, bounced off, hit the surface and then rolled. The shroud is 12 inches (30cm) long and 4-1/2 inches (11cm) in diameter. The big rock just beyond it is about 24 inches long and 12 inches thick. NASA photograph.

Discussion about the next stage centers around two options — a rover or a penetrator mission. The rover would land in one spot and drive under remote control to other regions — perhaps as much as several hundred miles away! The rover would have the advantage of being able to select geologic sites and individual samples for intense study.

The penetrator mission involves dropping several torpedolike devices that would bury themselves in Martian soil, making on-site measurements. This concept has the advantage of being cheaper, and also recognizes that Mars has many different kinds of geologic provinces — including volcanos, polar carbon dioxide ice fields, polar water ice fields, and chaotic terrain — too far apart to be sampled by one rover. Either type of mission would define the range of conditions on Mars more broadly than the detailed data from the two specific Viking sites.

A follow-up mission might be an automated sample return mission. The sample might be flown to a spacelab in orbit around Earth, to avoid contamination by (or of) Earth organisms. This would allow the first accurate dating and chemical analysis of Martian soil and rocks, giving the first precise time scale for the geologic history of Mars. Missions of this type may come in the 1980s or 1990s.

In the background of all such mission-planning is the dream of a manned mission to Mars. Aside from the intangible sense of exploration and adventure, this would allow greater discrimination in selecting geologic features and samples for study. Recent press accounts have reported vague but official discussions of a possible joint Soviet-American manned expedition to Mars. Any such expeditions could probably not be mounted much before the year 2,000.

In summary, what Viking has accomplished so far are important soil and atmospheric discoveries, putting limits on Martian biology, and definition of a new round of more sophisticated questions to which we would like to have answers.

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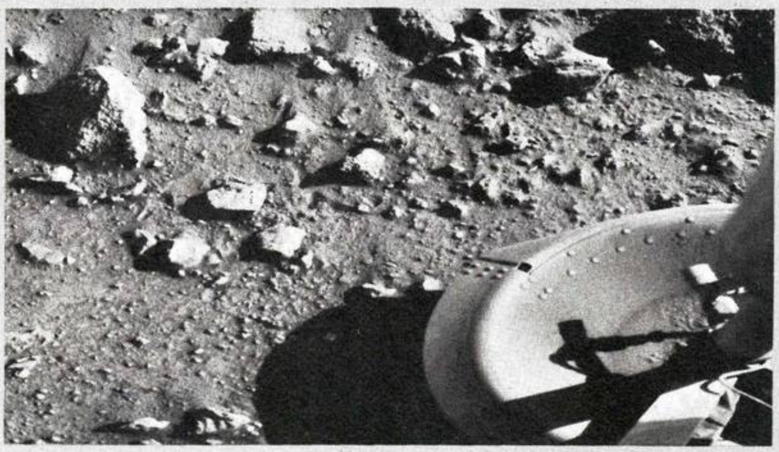

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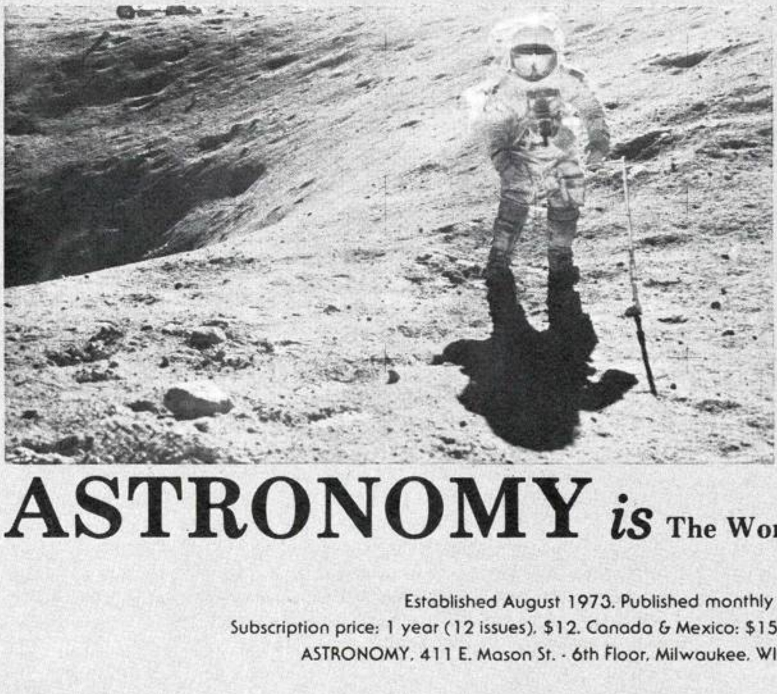

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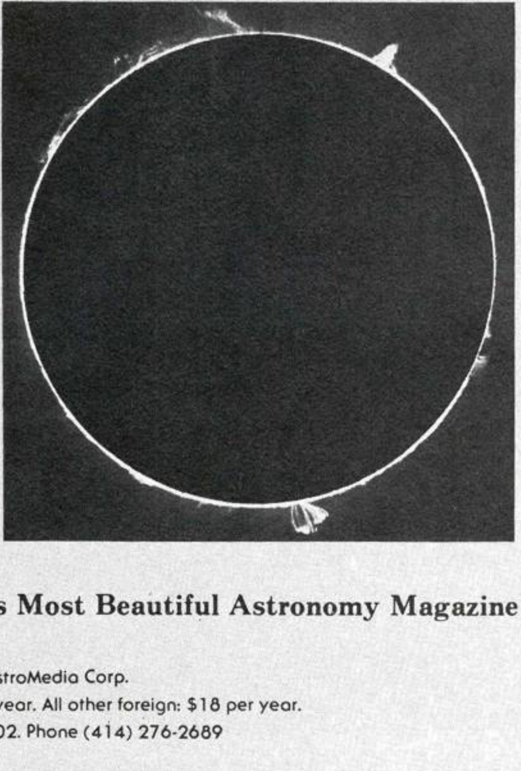

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LIFE ON MARS: AMBIGUOUS RESULTS

by
Thomas A. Easton

Is there life on Mars? It's hard to say, but we've spent millions of dollars in the effort to find out. We've designed and built two Viking spacecraft, and sent them to land on Mars to answer our questions about the red planet. And, they have performed successfully — in fact, beyond all expectations! The few equipment problems that have occurred have been almost too trivial to believe. But we still don't know for sure that there is, or is not, life on Mars.

Let's look at the results thus far obtained by the biology experiment package, and what they may mean. In examining the real nitty-gritty of the results, you'll understand the Viking scientists' dilemma.

Viking I landed in Chryse at 4:53 a.m. PDT, July 20, 1976, on the seventh anniversary of the first manned landing on the moon. It took 19 suspenseful minutes for its message of success to reach Earth. The tension was similar to that of a bowler trying for a strike. The suspense of waiting for the results of Viking's various experiments, however, was lower keyed and more lasting. Like the tension of the tournament bowler, building with every frame and string, each one hanging on the next, it has not yet been totally relieved.

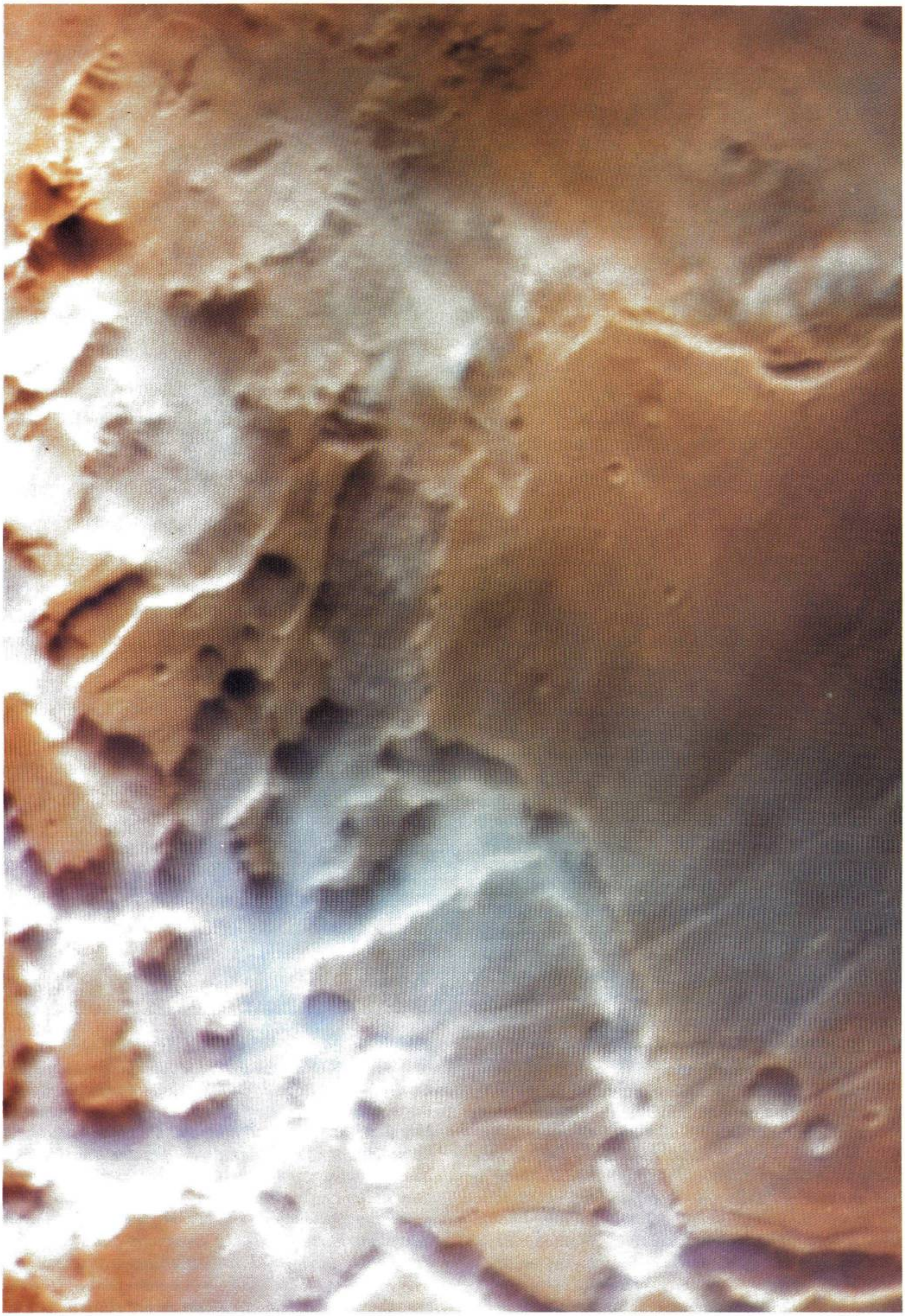
Viking's cameras have shown us the pink sand and rock we anticipated. They have also shown us a pink sky, which we did not expect. Photos taken from orbit have multiplied the types of terrain we know are there, recorded clouds and morning haze, and told us there is far more water than we had thought. The signs of water — eroded channels, teardrop islands and flood plains — have, in fact, proved abundant (see Astro-News, September 1976). Other instruments have told us the planet's overall temperature ranges from -200 to -30 degrees Fahrenheit, with the range at the Viking I landing site a warm -120 to -20 degrees. The atmospheric pressure is less than 1/100 (.0076) that of Earth's. Martian air is 95 percent carbon dioxide, 2 to 3 percent nitrogen, 1 to 2 percent argon, and .1 to .4 percent oxygen, with traces of such other gases as carbon monoxide and krypton.

The data — especially the presence of water — all bear on the possibility of life on Mars, but cannot answer our question. For that, we must look to the experiments which were designed to look for life: the gas exchange, label release and pyrolytic release experiments, backed up by a soil analyzer (the gas chromatograph/mass spectrometer, or GCMS). Each experiment is performed on a soil sample collected by the arm on the Viking lander; thus, we are fortunate that malfunctions of the arm on both landers have been only temporary.

The *gas exchange experiment* measures changes in the composition of the atmosphere over a soil sample after the addition of water vapor or a nutrient solution. One cubic centimeter of soil was scooped up and delivered by the lander's arm. Once the sample was in the test cell, .57cc of nutrient solution was added to a well at the bottom of the cell. Water vapor from the solution thus moistened the sample. This sample was then incubated in the dark at 8 to 10 degrees Centigrade (about 50 degrees Fahrenheit) for several sols (Martian days), and the atmosphere over the sample was monitored by a gas chromatograph.

The unexpected results were both dramatic and

As the sun rises over Noctis Labyrinthus, bright clouds of water ice can be seen in and around the canyons in this high plateau region of Mars. The clouds show vividly white or pale blue against the rust color of the desert. The fact that the clouds cling to low areas, only spilling over the canyon rim in a few places, puzzles scientists. It may be that water which condenses during the afternoon in shady eastern canyon slopes is vaporized as the sun falls on the slopes the next morning. The region shown is about 60 miles (100 kilometers) on a side. NASA photograph.

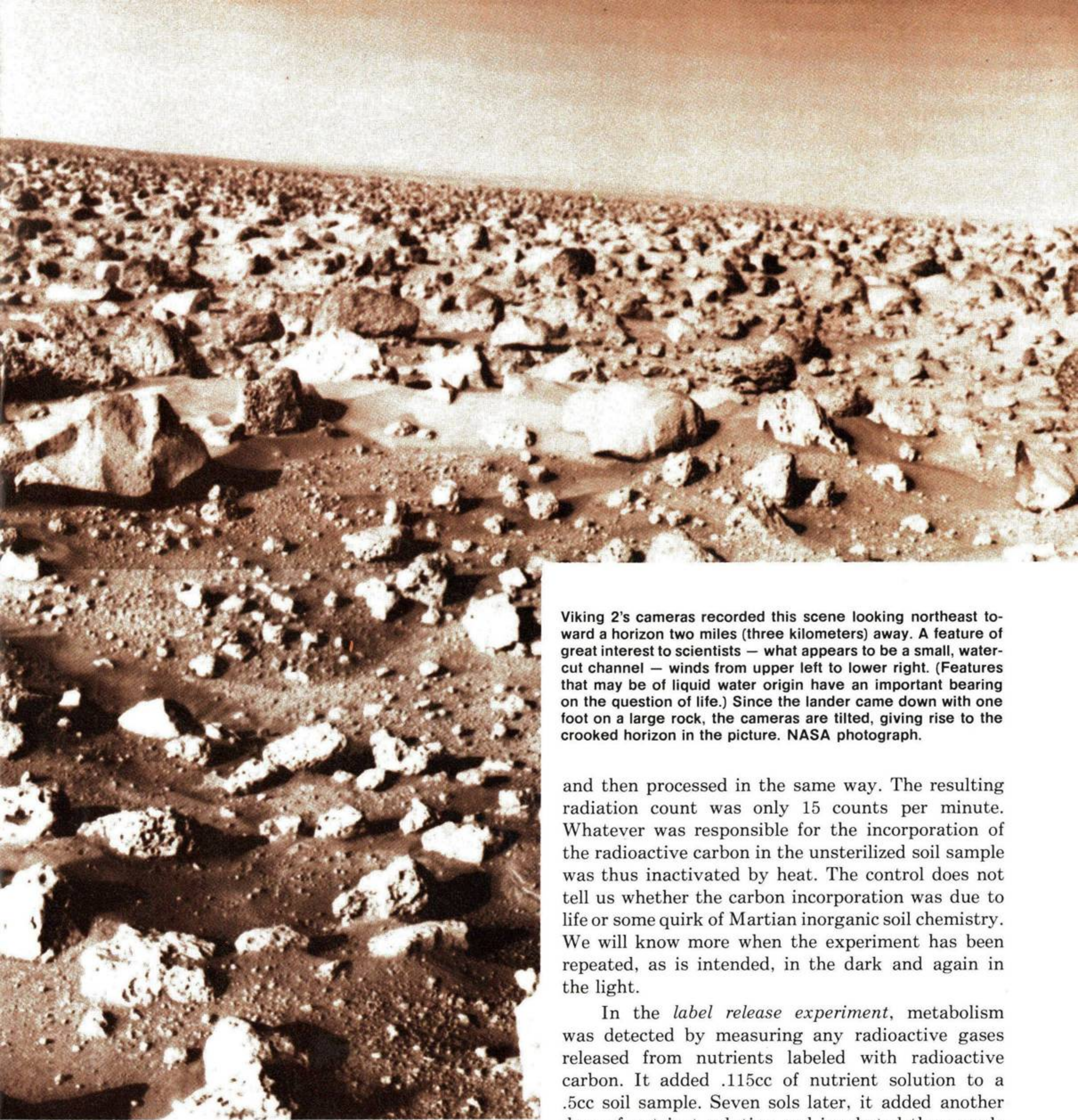


somewhat confusing: They spoke both for and against the possibility of life. Some carbon dioxide (CO_2) was released, peaking after two sols and then declining slightly, but the gas released from the soil in the greatest amount was oxygen (O_2). Its concentration rose very quickly and leveled off after about three sols. Because the experiment was carried out in the dark, oxygen release could not have been the result of photosynthesis. Viking scientists are, therefore, suggesting that it came from peroxides, superoxides or ozonides present in the soil. If they are right, life on Mars may be unlikely, for all those substances are potent oxidizers and would remove organic material if it were present. If life were protected against them, however, they might even represent an exploitable resource. The Martian atmosphere does not contain much oxygen, and an organism would be unable to extract much for its metabolic needs. Instead, it could extract oxygen from the soil.

After eight sols of incubation, an additional 2.27cc of nutrient solution were added to wet the soil sample. At this point, the carbon dioxide concentration promptly dipped, but then rose again while oxygen decreased. The oxygen may have been consumed by reacting with one of the added nutrients (abscorbic acid). This reaction would also have generated additional carbon dioxide, but the changes in the levels of both gases could be consistent with some form of life. We will have a better idea of the implications of the gas exchange experiment's results after the experiment has been repeated and a control (the same test on a preheated, "sterilized" soil sample) is run.

The *pyrolytic relase experiment* measured the incorporation of radioactive carbon dioxide and monoxide (CO) into the organic fraction of a soil sample. It added radioactively labeled CO_2 and CO to a 4cc test cell which held a .25cc soil sample together with some of the Martian atmosphere. The sample was illuminated by a lamp designed to mimic Martian sunlight, and incubated for 120 hours at about 16 degrees Centigrade (60 degrees Fahrenheit). No water vapor was added, although the option does exist.

After the incubation period, the test cell was heated to 120 degrees Centigrade (248 degrees Fahrenheit) and all gases, including any remaining radioactive CO_2 and CO, were removed. The cell was then heated to 625 degrees Centigrade (1,157



Viking 2's cameras recorded this scene looking northeast toward a horizon two miles (three kilometers) away. A feature of great interest to scientists — what appears to be a small, water-cut channel — winds from upper left to lower right. (Features that may be of liquid water origin have an important bearing on the question of life.) Since the lander came down with one foot on a large rock, the cameras are tilted, giving rise to the crooked horizon in the picture. NASA photograph.

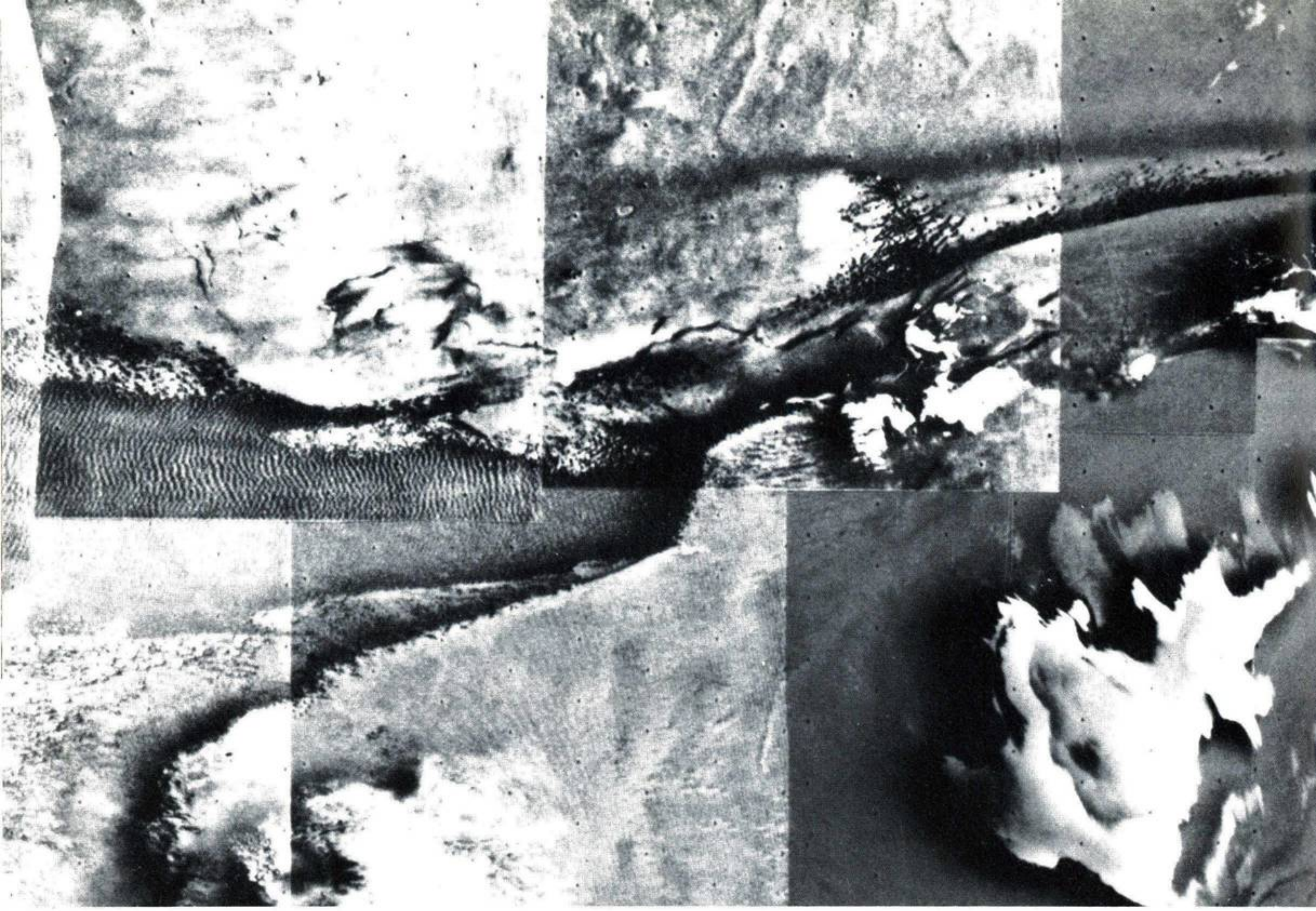
degrees Fahrenheit) to vaporize any organic material, the organic material was oxidized to CO_2, and the CO_2 was run through a radiation detector. If no radioactive CO_2 or CO had been incorporated into the soil, the detector would have counted only about 15 radioactive decays per minute. In fact, it counted 96 — 81 of which had to be due to incorporation of the radioactive carbon into the soil, presumably as organic compounds. This clearly suggests the possibility of life, and the suggestion is made stronger by a control experiment that was performed. A second soil sample was heated to 175 degrees Centigrade (347 degrees Fahrenheit) for three hours and then processed in the same way. The resulting radiation count was only 15 counts per minute. Whatever was responsible for the incorporation of the radioactive carbon in the unsterilized soil sample was thus inactivated by heat. The control does not tell us whether the carbon incorporation was due to life or some quirk of Martian inorganic soil chemistry. We will know more when the experiment has been repeated, as is intended, in the dark and again in the light.

In the *label release experiment*, metabolism was detected by measuring any radioactive gases released from nutrients labeled with radioactive carbon. It added .115cc of nutrient solution to a .5cc soil sample. Seven sols later, it added another dose of nutrient solution and incubated the sample for six sols more at about 10 degrees Centigrade (50 degrees Fahrenheit). The air space over the sample was monitored by a radiation detector.

Almost as soon as the first dose of nutrient solution was added to the soil sample, radioactive gas appeared. The quantity released leveled off after about one sol. It amounted to about as much radioactive gas as would be obtained by the oxidation to carbon dioxide of one carbon in one of the seven nutrients in the nutrient solution. The second dose of nutrient solution provoked an abrupt increase in the release of gas, followed by a rapid decline (meaning that some gas may have been absorbed by the soil sample or dissolved in the added solution), and then by a slow rise again. In the control experiment, a fresh soil sample was sterilized by heating to 170 degrees Centigrade (338 degrees Fahrenheit) for three hours, but there was no release of gas beyond that which could be accounted for by nonbiological processes.

The Viking II lander, much nearer the north polar cap in Utopia, had not completed its biology experiments when this article was written (October). The results it had obtained do, however, confirm those from Viking I. The gas exchange experiment also found a release of oxygen from moistened soil, but the amount of O_2 was 20 percent less — suggesting either less life in more northern soil or a less active soil chemistry. The latter could be expected if the gas exchange results are due to peroxides, superoxides or ozonides in the Martian soil. There is about three times as much water in the air at the Viking II site, and water would tend to degrade these substances.

Viking II's label release experiment, however, found a 30 percent *greater* release of radioactive gas from the labeled nutrients. This result suggests either more life or a more active soil chemistry. The former possibility is to be expected if there is life on Mars at all because of the greater amount of available water near the pole, but the latter is a puzzle. It contradicts the gas exchange results.



The polar caps of Mars are active: Ice, water and sand are moved by the wind in fascinating patterns. At the edge of the northern polar cap, giant dune fields are recorded by Viking 2 orbiter television cameras. Dark mobile sand streams down a curving channel into the delta shaped dunefield, distinguished by wavy ridges. Toward the lower left, the solid mass of sand breaks down into a discontinuous covering of dunes in linear patterns. NASA photograph.

Taken all together, the Viking biology results definitely suggest that there is life on Mars and that there are some differences in metabolic patterns between regions. They do not do more than suggest, because they can be explained in ways that do not involve life (at least in part). Life is the simplest explanation, however, and the Viking results invite a certain amount of speculation as to just what kind of life it is. Our speculations must be restrained, though. We cannot populate Mars with anything more than a few microorganisms, for the Viking cameras have shown us nothing large, and the soil analyzer (the GCMS) has so far failed to detect organic compounds in the soil of either the Viking I or Viking II site. Organic compounds would be expected to be there if there is life, since living cells would be made of them and dead cells would leave them in the soil. We might expect only the compounds in living cells to be available for discovery, though, since the high ultraviolet flux on the surface of Mars and the presence of peroxides or other oxidizing substances would destroy unprotected compounds.

The failure of the GCMS to find organic compounds is not, however, as much of a blow to our hopes as it seems. The GCMS was not designed as a life detector, and its sensitivity is such that it would fail to detect as many as a million Earthly bacteria per gram of soil. If Martian life does exist and is anything like Earthly life (and the Viking results do suggest that it must be at least recognizably so; otherwise we should have seen no signs of carbon metabolism), it cannot be more abundant than the equivalent of a million bacteria per gram of soil. It is interesting that the GCMS *did* find a fair amount of water in the soil — at least .1 to 1 percent of the soil's mass. Viking scientists are attributing this water to mineral hydrates, but it is possible that it could be a sign of life. Living cells on Earth are about 98 percent water, and in a water-scarce environment (where cells could store water), the percentage could be higher.

Data so far obtained are ambiguous — but if it points at all clearly in any one direction, it is toward life. While the gas exchange results can be explained by nonbiological soil chemistry, the label release and pyrolytic release results can be accounted for in this way only with difficulty. We are hardly justified in saying there is no life on Mars, even though we also cannot say there clearly *is* life there. We can, however, make some assumptions and try to imagine what Martian life must be like if the Viking results are indeed its signs.

We certainly have the same reasons we had befor Viking to believe life must be on Mars. The planet has a great deal of water — the polar caps appear to be almost entirely water and as much as a kilometer (about .62 mile) thick — which may once have been a free-flowing liquid. Like Earth, Mars was formed from the dust and gas of the solar nebula, and its first atmosphere must have contained the same organic compounds that gave rise to life on Earth. The atmospheric pressure may once have been between 1/10 and perhaps 2/3 of Earth's. The temperature would have been warmer — there is recent evidence that Earth's temperature was nearly 160 degrees Fahrenheit until about three billion years ago — and all the necessary chemical reactions could have taken place. The organic compounds would have been acted upon by solar radiation, lightning and the planet's internal heat. They would have reacted with each other to become amino acids (the components of proteins) and the other building blocks of life. Life should have arisen on Mars as it did on Earth. It might have needed only a few hundred million years of wet and warmth to get its start. It may have had much more time, if the high temperature on Earth during its first two billion years was caused by a hotter sun.

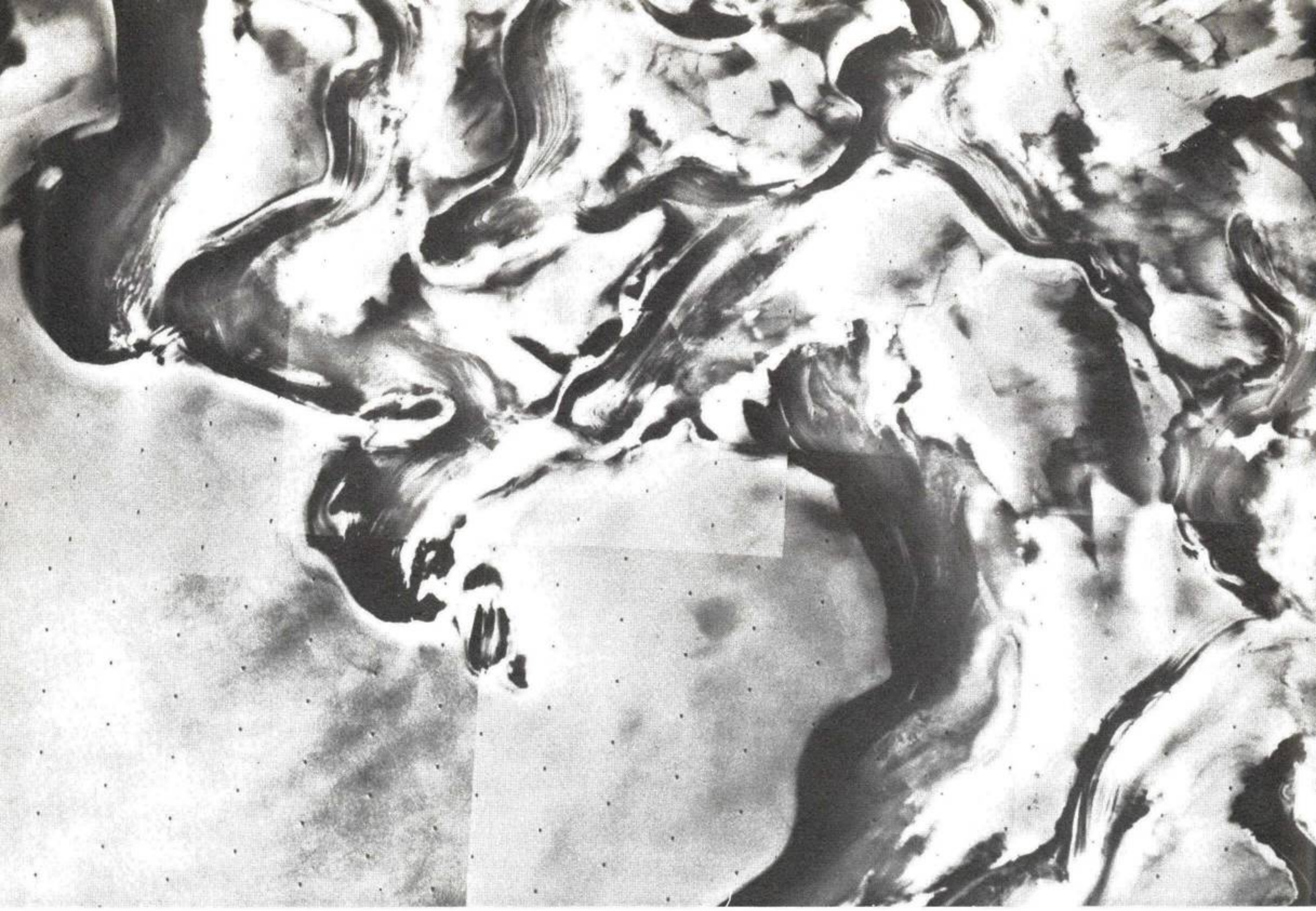
Once started, Martian organisms would have quickly evolved to cover the planet. They would have been found everywhere, from the most hospitable seas to cold, dry, hostile mountaintops. When the planet began to turn cold and dry, the mountaintop life forms would have moved down into the valleys and lowlands, thriving wherever conditions were something like their earlier homes and adapting to even harsher conditions. They should still be there, for the warmest, wettest spots on Mars today are not much different from Earth's mountaintops (where forms of life do exist).

Because Mars has probably been in something like its present state for most of its existence, its life forms — if they ever existed — probably never evolved beyond the stage of bacteria, algae and fungi. If they had reached the stage of animals and higher plants, the Viking cameras might have been expected to record some signs of them. If we are to speculate on the nature of Martian life, we must, therefore, restrict ourselves to microscopic life forms. We must ask how it must resemble Earth life and how it must differ. And we must stay within the bounds sketched by the Viking biology results.

First, the failure of the GCMS to find organic compounds in the soil, coupled with indications from the label release and pyrolytic release experiments that Martian organisms do have an organic chemistry, shows that there must be relatively few organisms in the soil. It gives us no clue as to whether they live between soil particles — as is common on Earth — or in the sheltering cracks beneath the surfaces of soil particles and pebbles, as do some algae in Antarctica and in Israel's Negev Desert.

By itself, the pyrolytic release experiment suggests a relatively fast metabolism, for when the experiment was performed on soil samples from Antarctica, much less carbon was taken up within the soil. Whatever the Martian organisms are, they are well adapted to their frigid environment.

The label release experiment suggests certain peculiar differences from the metabolic behavior of Earthly organisms: The release of radioactive gas leveled off in about 1/3 the time it does with an Earthly soil sample. Also, the amount of gas released indicates that Martian organisms cannot use as many, or the same, nutrients as Earthly organisms. Only one of the seven nutrients added to the soil sample appeared to be metabolized, and then only partially. This may mean, for instance, that Martian life is left-handed where Earthly life is right-handed, and vice versa. On Earth, organic molecules are made and consumed by living things only as one of two possible optical isomers. The complexity of their structures allows them to exist in two mirror-image forms. When they are put in solution, these forms polarize light, rotating it either to the right or to the left. And only one form of a molecule appears in Earth's living things. Amino acids, for example, are left-handed; they rotate light to the left. Sugars are right-handed, rotating light to the right. On Mars, it may be the other way around, so that organisms from the two planets

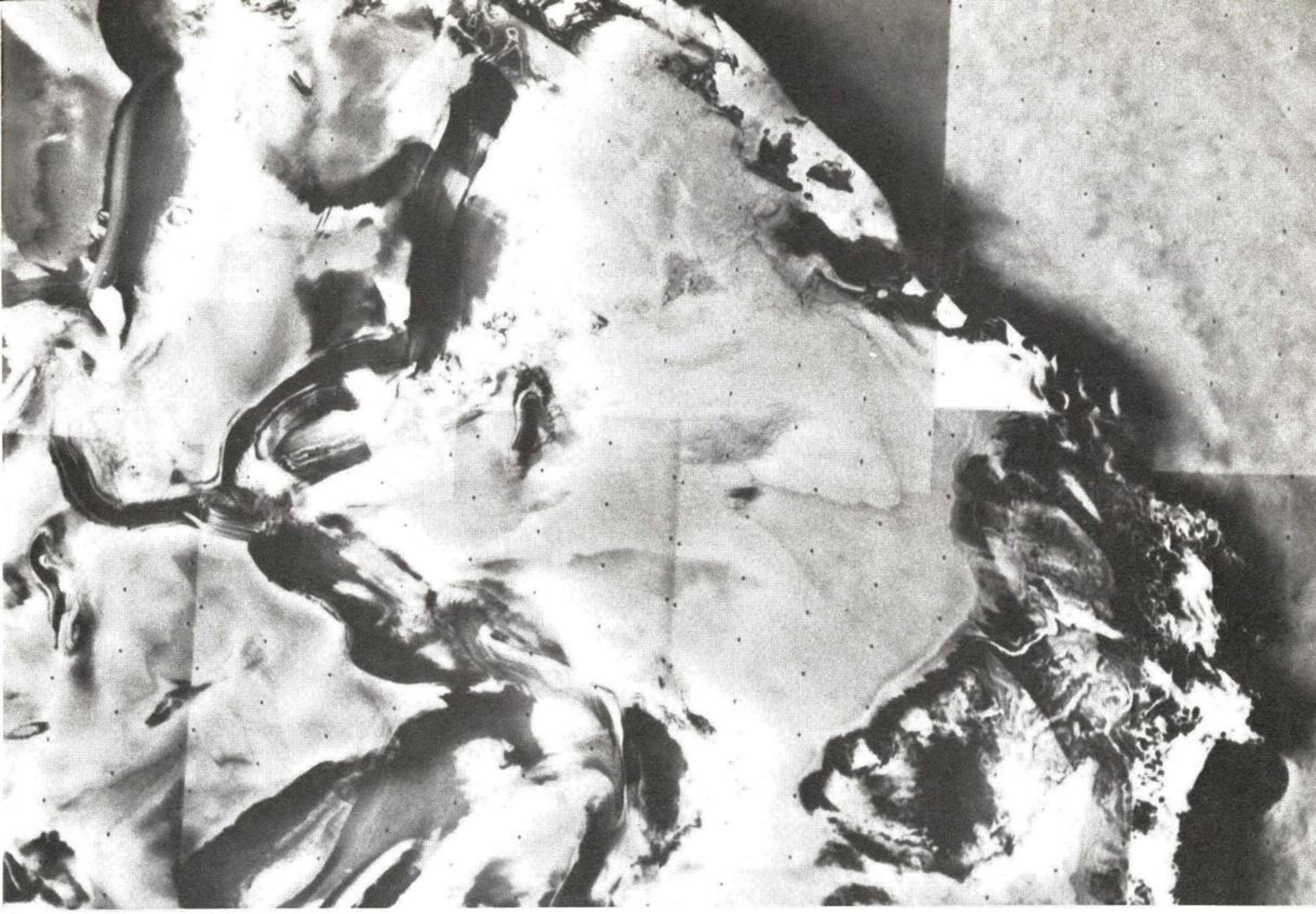


would have trouble eating each other; they would be mutually indigestible. We may therefore not have to worry about importing new diseases from Mars, though an "Andromeda strain" remains conceivable on other planets.

The most puzzling information comes from the gas exchange experiment. The release of carbon dioxide could simply be a sign of metabolism, but the release of oxygen is difficult to understand if it is not due to Mars' inorganic soil chemistry. One way to approach the problem may be to look at the timing. The oxygen concentration rose before that of the carbon dioxide, and leveled off after. If Mars' soil does contain peroxides, superoxides or ozonides which give off oxygen when moistened, this may be a sign of a life form with a peculiar ability. As suggested in connection with the GCMS results, Martian organisms may store water. The storage probably occurs very slowly since water is scarce. Once enough has been collected, however, the organism might release it into the soil where it would react with the oxygen releasing substances. The organism would trap the resulting oxygen and use it to metabolize nutrients and produce the carbon dioxide also detected in the gas exchange experiment. The organism would then move into fresh, unmoistened soil, or perhaps grow into it as a filament. The soil would presumably be recharged with oxygen by inorganic chemical processes, or perhaps even by a different, photosynthesizing organism which makes oxygen available not as a gas, but as a peroxide. There is also the possibility that such an organism might store the oxygen it produces and release it upon contact with water. The two organisms — the oxygen producer and the oxygen consumer — might even be the same, or they might be partners in a tight, closed circuit symbiosis.

Oxygen was detected in the gas exchange experiment because presumably more was released than the soil organisms could trap. Its concentration later declined because they were consuming it and the presumed peroxides had been exhausted by the water vapor added at the beginning of the experiments. There was none left for the water added later to react with.

We can summarize our speculations by saying that if life exists on Mars, it must be microscopic, scarce, and able to function in extreme cold. Its metabolism is apparently based on compounds of carbon, oxygen and hydrogen, and though it may use compounds not used by Earthly life, it surely uses water. It may occupy the interiors of soil particles for protection from the environment. Nonphotosynthetic organisms may spend large periods of time in a dormant condition, with their only activity being to collect water. When they have accumulated enough, they may "awaken" to use the water to provoke the release of oxygen from soil



From the Viking 2 orbiter, Mars' polar caps continue to bring surprises to Viking scientists. Here, in the northern polar cap, a spectacular array of new features is revealed. Translucent streaks — overlying both icy and ice-free zones — had never before been seen. They may be the result of wind blown ice and dust particles. At the edges of large ice patches, complex patterns of layered ice and soil can be seen. NASA photograph.

chemicals, trap it, and use it to metabolize nutrients, reproduce, and move. They would live in spurts, and would be geared to an intermittent life cycle. They may well be completely unable to take full advantage of extremely favorable conditions, such as those offered by a Viking test cell, which might explain some of the anomalies in the Viking results.

Photosynthetic organisms, on the other hand, could live continuously (during the day), the pace of their lives being determined only by the supply of water. They would use light to produce oxygen, but probably not as a gas. It would be retained within the organism or stored in the soil as peroxides, superoxides or ozonides, and would be released upon contact with water.

If there is life on Mars, this portrait has a good chance of being in the ballpark. It is consistent with the limited data we now have. However, the data are ambiguous. According to Harold Klein, NASA scientist in charge of the Viking biology team: "The instruments, like a fishhook, have snagged something in the Martian soil — but that something could be a fish or just an old boot." We will know more when the complete experimental program has been carried out, but will have to wait for nearly a year before the last returns are in. The experiments will incubate their last soil samples for at least 200 days, with the scientists hoping for more definite data. Some Earthly soils, for instance, refuse to show signs of life until they have been incubated for 100 to 150 days.

But the final results should not change our present picture too much. We have plenty of data. Our main difficulty is that these first pioneering experiments are perhaps too general to give us more than tantalizing hints of the truth. A final answer will probably require returning a sample from Mars. A sample return mission is tentatively scheduled for the late 1980s. During the next few decades, we should see the complex question of life on Mars answered.

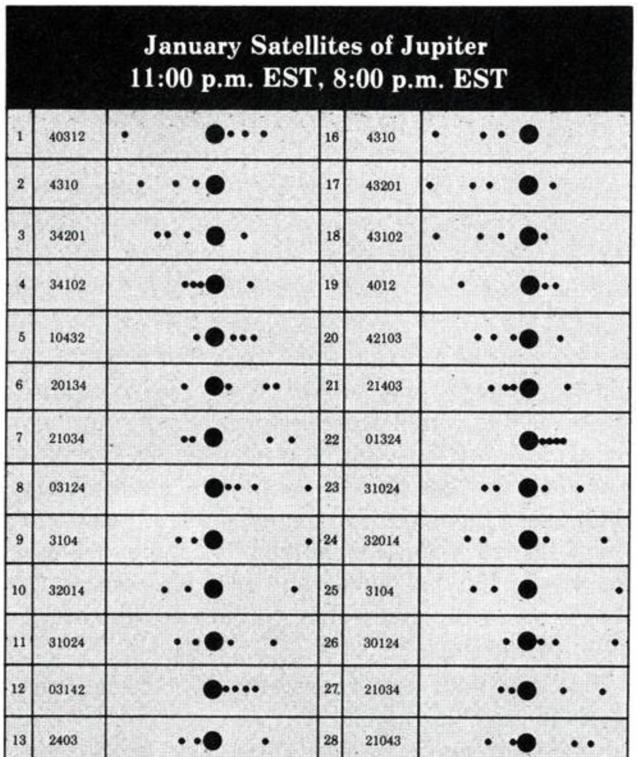
Dr. Thomas Easton is a theoretical biologist and free-lance science and science fiction writer. He is currently working, under contract, on a biology textbook.

Easton is disappointed about the results of the life detection project and feels the Viking scientists must be disappointed too. "They put sweat and tears into it. I only stuck my neck out and predicted Viking would find life on Mars." (ASTRONOMY, July 1975). He feels that, win or lose, there is a great deal of pleasure and satisfaction to be derived from the discoveries that have been made.

SKY ALMANAC

Venus Is Hard to Miss

During 1976, the planets were fairly bunched together in the sky, and the summer months offered relatively little in the way of planetary observation. This year, 1977, promises more of the same; after six months filled with a rapid succession of planetary elongations and oppositions, the second half of the year will "suffer" a severe paucity of such events. Planetary observers are therefore advised to gear up for an active first half of 1977, after which they'll have to turn to other astronomical pursuits.



January Satellites of Jupiter
11:00 p.m. EST, 8:00 p.m. EST

1	40312	• ●•••	16	4310	• ••●
2	4310	• ••●	17	43201	• •• ● •
3	34201	•• • ● •	18	43102	• •• ●•
4	34102	•••● •	19	4012	• ●••
5	10432	•●•••	20	42103	•• •● •
6	20134	• ●• ••	21	21403	•••● •
7	21034	••● • •	22	01324	●••••
8	03124	●•• • •	23	31024	•• ●• •
9	3104	••● •	24	32014	•• ●• •
10	32014	• • ● •	25	3104	•• ● •
11	31024	••●• •	26	30124	•●•• •
12	03142	●••••	27	21034	••● • •
13	2403	••● •	28	21043	• •● ••
14	42103	• ••● •	29	01423	●••••
15	40312	• ●•••	30	42103	•••● •
			31	43201	••• ●•

The four major satellites of Jupiter orbit the giant planet in periods ranging from just under 2 days to 17 days. They can be seen to change position from night to night. Sometimes their motions become evident after only a few minutes' observation. Only a small telescope is required to detect all four of the satellites and several can frequently be seen in rigidly held binoculars. This table shows the approximate positions of the moons at about 11 p.m. (EST) on the evenings indicated. First column on the left shows the date. Second column of numbers identifies the moons and their positions relative to Jupiter's disk. (1=Io; 2=Europa; 3=Ganymede; 4=Callisto, and 0= Jupiter's disk.) The third column approximates a telescopic view of the satellites' positions. The orientation of the satellites is shown inverted as seen in a standard astronomical telescope.

Mercury, Venus

Both inner planets reach greatest elongations in January, but on opposite sides of the sun. Mercury's occurs on Jan. 29, when it is at greatest western elongation, appearing in the morning sky. This will, however, be an unfavorable time to view the smallest planet because of the low angle of the ecliptic above the horizon; Mercury's low altitude will prevent effective telescopic observation. Its magnitude on the 29th will be +0.1, so it should be easily visible to the naked eye just before sunrise for a few days at the end of the month.

Venus' greatest eastern elongation on Jan. 24 marks the end of the planet's eastward trek against the star background that began on June 18, 1976, when Venus was in superior conjunction with the sun. On the 24th, Venus will dazzle the eye with a magnitude of -4.0, and will set about three hours after the sun, giving observers a rare chance to catch a glimpse of the planet in a completely dark sky. Through the telescope, Venus will exhibit a phase of exactly half at opposition; its apparent diameter will be 24.28 seconds of arc, and its distance from Earth will be slightly more than 64 million miles. In the months ahead, Venus' disk will gradually enlarge and the planet will brighten as it moves closer to Earth.

Corona and prominences burst from the sun, made visible by the intervening lunar disk in these photos obtained from a site near Mansfield in Victoria, Australia, on Oct. 23, 1976. Both photos were taken through a thin layer of cirrus clouds; the sky had been totally obscured until just after totality began. ASTRONOMY Magazine Australia Expedition Photographs by Brad Wallis and Bob Provin, copyright© 1976 by AstroMedia Corp.

Above left: The moon and Jupiter rise above the trees in an Aug. 18, 1976 view from Bristol, Va.; the Pleiades can be seen at upper left. This is a 30 second exposure with a 135mm lens at f/2.8. Photograph by Lee Allen Newton. Above right: One month later, Jupiter's proximity to the Pleiades presented a pleasing sight. This 10 minute exposure on GAF 200 was obtained with a 135mm lens at f/2.8. Photograph by Hal Jandorf. Opposite page: Several different views of Jupiter near opposition are seen here. Upper left: This is a one second exposure on Kodachrome 64, obtained with a homemade six inch Newtonian at f/47. Photograph by L.H. Price. Upper center: This three second exposure on Kodachrome 64 shows remarkable detail, as does the one second exposure at upper right, made on High Speed Ektachrome. Both photos were made on Oct. 24, 1976 through a 14 inch Schmidt-Cassegrain at f/98. Photographs by Steve Reed. Lower left: The shadow of Jupiter's largest satellite, Ganymede, is in transit near the bottom of Jupiter's disk in this photo. Ganymede itself can be seen just off the planet's disk. This two second exposure, made at 10:30 p.m. EST on Nov. 5, 1976, is on GAF 200 pushed to ASA 400; it was obtained through a homemade eight inch Newtonian. At lower center and right, the shadow of Io crosses Jupiter's disk. These are two second exposures on GAF 500, taken on Nov. 6, 1976. Photographs by Bob Kimmel.

Jupiter

Presently high in the south at sunset and setting shortly after midnight, Jupiter resumes forward motion on Jan. 15. Located in Aries near the Taurus border and not far from the Pleiades, the giant planet's magnitude decreases during the month from -2.2 to -2.0, while its apparent diameter shrinks from 42.54 to 39.06 seconds of arc. Jupiter will not be as large and bright again this year until November.

Saturn

The ringed planet reaches opposition early next month, and will be in good position for viewing throughout January. Saturn shines near the eastern border of Cancer at magnitude +0.1 during most of the month. As it nears its closest approach to Earth, Saturn's distance from us decreases from 773 to 758 million miles.

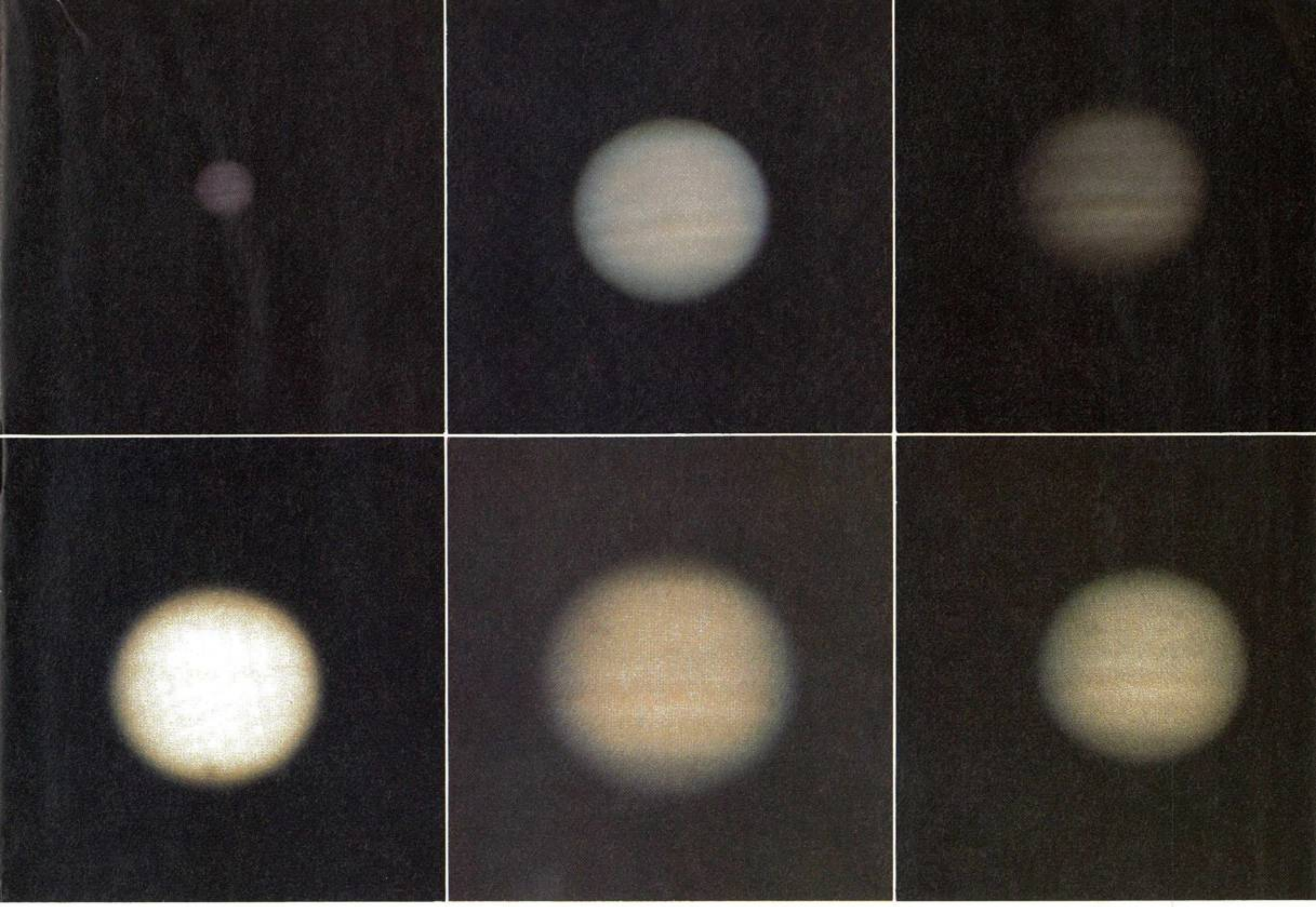
Mars

Mars is still too close to the sun to be easily visible during January.

Asteroids

All the "big four" asteroids will reach opposition during the first half of 1977. The first will be Vesta, brightest of the four, which is at opposition in the constellation Gemini on Jan. 9. At that time, its magnitude will be about 6.6 — necessitating telescopic observation of this "naked eye" minor planet. For Vesta's position, consult the map that appeared in the December 1976 Sky Almanac.

Pallas will be at opposition on Feb. 10 in the dim southern constellation Pyxis; it will be located almost exactly on the border of the neighboring group Hydra. The reason for Pallas' position far from the ecliptic is the large inclination of the asteroid's orbit. Since there are no bright guide stars nearby, Pallas will be more of a challenge to find than Vesta, even though the two will have virtually



the same magnitude on their respective opposition dates.

Quadrantid Meteors

As has so often been the case with meteor showers in recent months, the moon will once again interfere with observation. The Quadrantid meteors (named after an extinct constellation; their radiant is in the northeast corner of Boötes) reach their peak only a day before the full moon, which will remain in the sky all night and prevent the shower from making much of an impression. For those who simply "must" observe meteors despite the poorest of conditions, the Quadrantids peak during the early morning hours of Jan. 4; their maximum rate is about 40 meteors per hour.

Satellite Shadows on Jupiter

Date	Satellite	Transit Begins (EST)	Transit Ends (EST)
Jan. 3	2	12:07 a.m.	2:38 a.m.
6	1	12:52 a.m.	3:02 a.m.
7	1	7:21 p.m.	9:31 p.m.
13	2	4:03 p.m.	6:33 p.m.
14	1	9:17 p.m.	11:27 p.m.
16	1	3:46 p.m.	5:56 p.m.
20	2	6:39 p.m.	9:09 p.m.
21-22	1	11:13 p.m.	1:22 a.m.
23	3	5:33 p.m.	7:48 p.m.
23	1	5:41 p.m.	7:51 p.m.
27	2	9:16 p.m.	11:45 p.m.
30	1	7:37 p.m.	9:47 p.m.
30	3	9:34 p.m.	11:50 p.m.

1 = Io
2 = Europa
3 = Ganymede
4 = Callisto

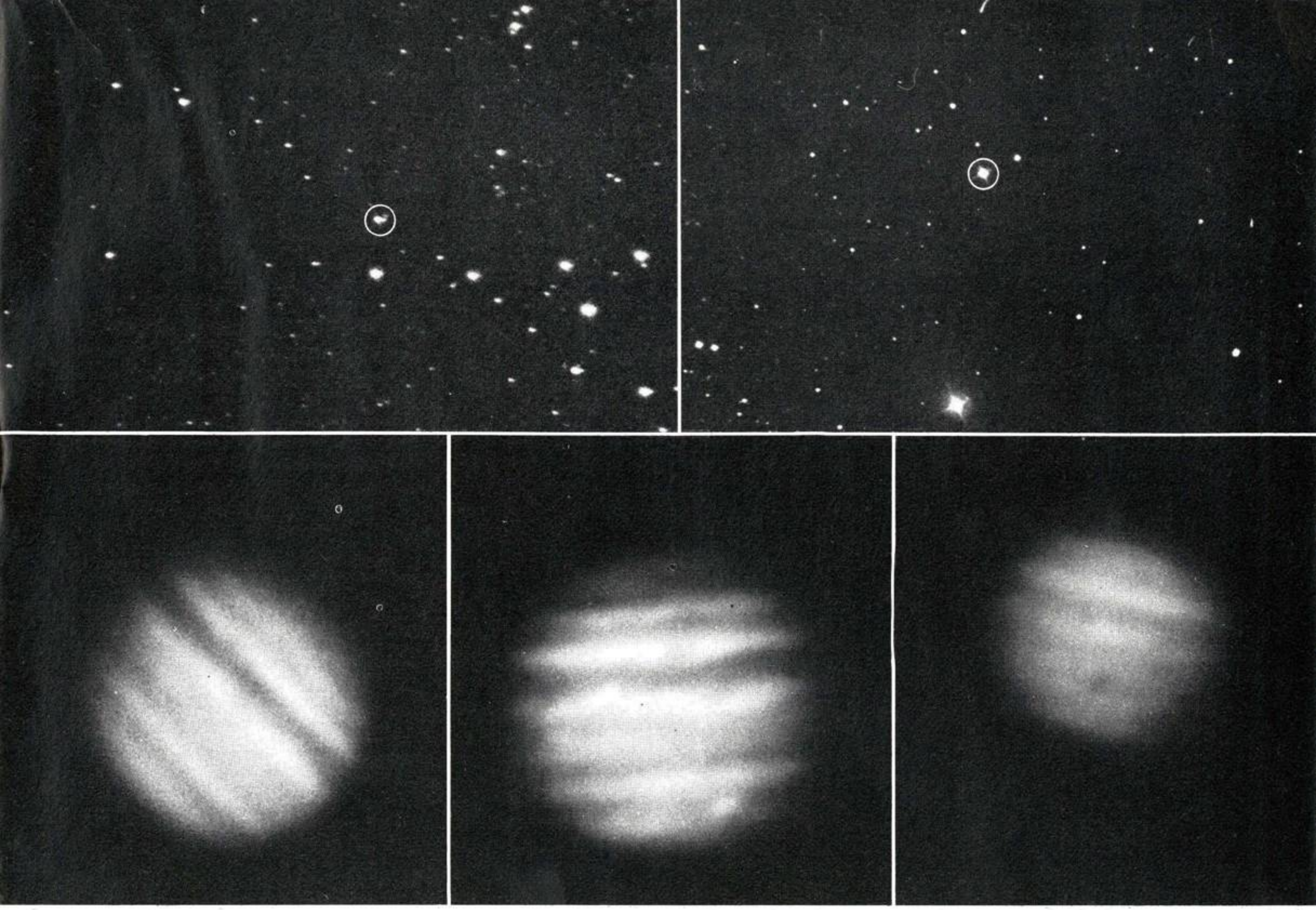
Nova Vulpeculae 1976

On Oct. 21, 1976, G.E. Alcock of the British Astronomical Association discovered a nova in the constellation Vulpecula. The nova was located in the "flying wedge" — a tiny, striking configuration of stars that includes 4 and 5 Vulpeculae, just north of the Vulpecula/Sagitta border and northeast of NGC-6802, a cluster of faint stars.

At its discovery, Nova Vulpeculae 1976 was already near its maximum magnitude of 6.5. Its position matched that of an 18th magnitude blue star on the Palomar Sky Survey photo of the region, and its distance was computed as about 1,800 parsecs (almost 5,900 light-years). Nova Vulpeculae was a "slow" nova, exhibiting none of the extremely rapid brightness changes that Nova Cygni 1975 underwent — although observers reported some fluctuations in brightness on Oct. 27. By the 29th, the nova had faded to about magnitude 7.3.

Total Solar Eclipse

The total solar eclipse of Oct. 23, 1976, visible from southern Australia, enticed a good many



Opposite: This splendid photograph of the first quarter moon is superbly detailed, and closely matches the moon's true color. This one second exposure on Kodachrome 25 was obtained with a Questar 3-1/2 at f/34. Photograph by Frank L. Calloway. Upper left: Nova Vulpeculae 1976 was discovered on the evening of Oct. 21, 1976. This photo, taken five nights later, shows its position just above the "flying wedge" asterism. The nova had an orange visual appearance. This is a 10 minute exposure on Kodak 103aE film, made with a 300mm lens at f/4.5. Photograph by Tom Koed. At upper right, a closer view of the nova is seen; the cluster NGC-6802 can be seen to the left. A 12.5 inch Newtonian at f/4.6 was used for this 10 minute exposure on Tri-X. Photograph by Jack Newton. Three more views of Jupiter are reproduced above. At bottom left is a one second exposure on H&W Control film, made through an eight inch Schmidt-Cassegrain at f/100 on Aug. 29, 1976. Photograph by Steve Reed. Bottom center: A homemade eight inch Maksutov at f/90 was used for this Nov. 2 photo — a four second exposure on VTE film. Photograph by George Nalisnik. Bottom right: The shadow of Io is in transit in this four second exposure on H&W Control, made Nov. 6 through a homemade eight inch, f/5 Newtonian. Photograph by Bob Kimmel. An additional note: Many observers have reported the lack of any trace of the Great Red Spot at this opposition.

observers and photographers from the United States to make the long trans-Pacific trip for a chance to see it. Unfortunately, the southern sections of Australia were undergoing a long bout with rainy weather, and many were clouded out. Still, the sun was able to break through the clouds long enough to permit Robert Provin and Brad Wallis — ASTRONOMY's official photographic representatives for this event — to obtain the photos on page 35, as well as others that will be featured in an extended Sky Almanac next month.

Photo Submissions

When you submit slides or prints of your astrophotos, be certain that your name and all pertinent information is included on **each** one of your submissions. We request this, because photos are filed by subject, and a letter containing related information is often separated from the photos. Remember that your picture may be kept on file for a year — perhaps even longer — until a slot opens that only your photo can fill, be it in Gazer's Gazette, Photography in Astronomy, or another departmental feature.

What kinds of pictures do we want? Your best chance for publication comes when your submission is something different and interesting, or illustrates a specific technique or method. Photos of some of the lesser known or less often photographed clusters, nebulae or galaxies are more than welcome at ASTRONOMY. (For instance, M-42 photos — even excellent ones — are often rejected because we get a lot of them.) Also, photos of current sky events, such as eclipses or conjunctions, are always useful: Witness the comet West pictorial in the May 1976 issue, or the photos of Nova Vulpeculae on this page. And don't forget that we like pictures that are just plain pretty.

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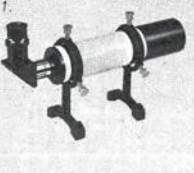

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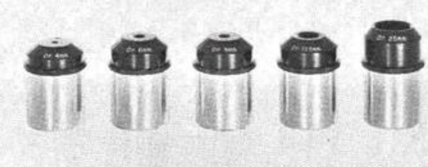

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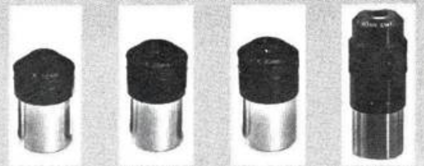

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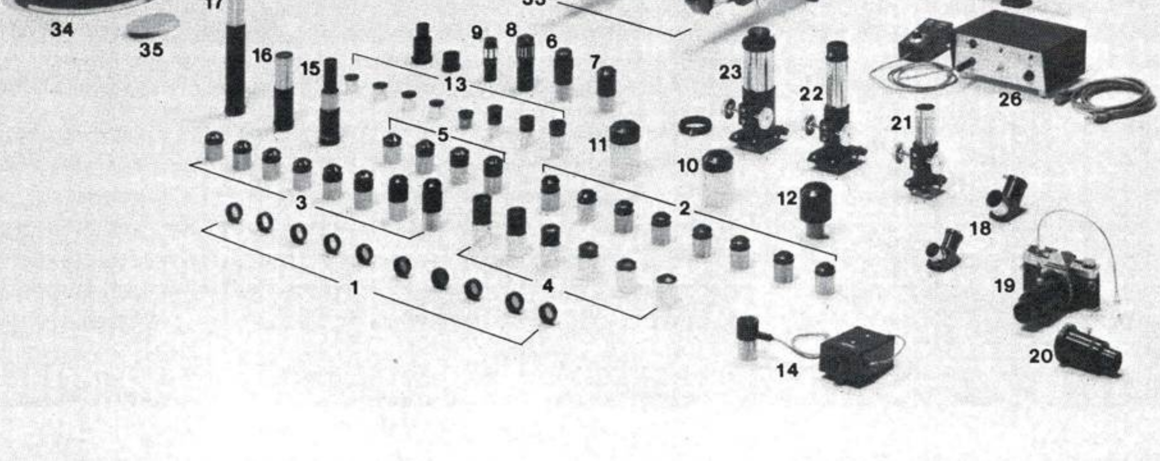

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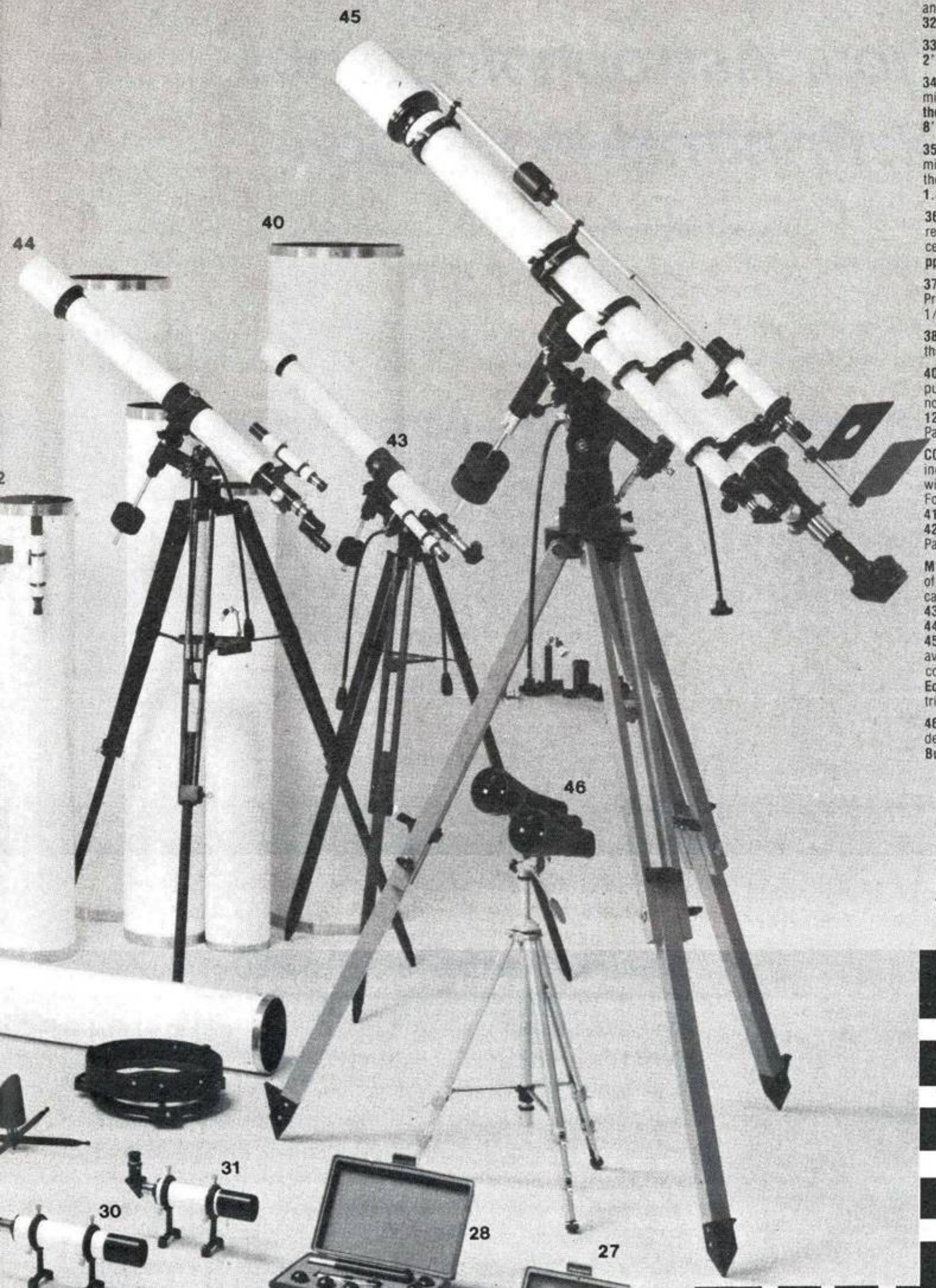

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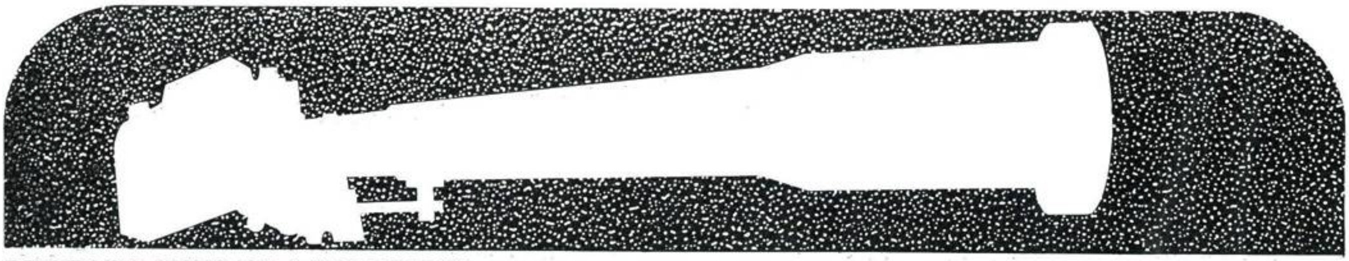


PHOTOGRAPHY IN ASTRONOMY

Printing Your Astrophotographs
Part 2: Printmaking Tricks

by
David Hudgins

"My prints are clean and sharp, but how can I get the sparkle and quality I see in prints of more experienced astrophotographers?" Beginners who have mastered the basics of printing, but are still eager and observant enough to desire the finest prints from their precious negatives, can learn from the tricks used by "old pros" to further improve their astrophotos.

High Contrast Printing

One way to improve many astrophotos is to use enlarging paper with a higher contrast grade — such as 4, 5 or 6 — rather than the normal 2 or 3. High contrast papers are made to exaggerate faint differences in tone: Dark gray areas become darker, while light gray areas print even lighter. Exaggeration of contrast can reveal details that would never be visible on normal paper. For example, what appears to be a sharp, but dull featured, Martian disk can be transformed into the kind of photo you're really after — one with definite surface markings and brilliant polar caps. These papers reveal more stars and nebulosity in deep sky shots. However, along with the benefits come a few drawbacks.

Successful use of high contrast paper requires extra time and care. Along with the astronomical detail, these papers also exaggerate everything else: dust and scratches in the negative, vignetting of the lens, and — perhaps worst of all — grain. This is a common problem in deep sky photography where the very grainy 103a films are frequently used. Overcoming such problems means additional work in the darkroom — experimentation with various grades of high contrast paper, plus learning a few tricks such as dodging, burning-in, and retouching.

Burning and Dodging

Sometimes a print seems to be correctly exposed overall, but small areas still appear either too light or dark. Details you can see on the negative do not appear on the print. This problem is due to the inability of enlarging papers — especially high contrast papers — to reproduce the full tonal range of most films. To compensate for this, every astrophotographer should know the simple tricks of burning and dodging.

You'll need to make four simple tools. Starting with three sheets of lightweight cardboard, cut holes 1/2 inch and 4 inches in diameter in the center of the first two, leaving one sheet just as it is. Then make a dodging "wand" — a 10 inch length of coat hanger wire with a one inch diameter disk of black paper taped to one end. Now you are ready!

Dodging is used to lighten selected areas of a print. One of the most common applications is to eliminate the unsightly darkening at the edges of a print caused by vignetting of the camera lens. To lighten areas, you must reduce the exposure time in those parts of the print by shading such areas from the projected negative image during a portion of the normal exposure time. Keep your cardboard with the four inch hole moving during dodging so that the inner areas of the print least affected by vignetting are dodged the least amount of time, while the extreme edges needing to be lightened the most are kept in the shadow of your dodging tool for a longer time. Constant movement allows you to blend areas requiring different amounts of dodging, and prevents recording the sharp outline of the dodging tool on your print.

Dodging rapidly lightens a particular area of the print. Be careful not to overdo it! Vignetting, for example, usually involves dodging the extreme edges of a print by about 30 percent of the normal exposure time. The less severely vignetted areas should be dodged for proportionately shorter periods of time.

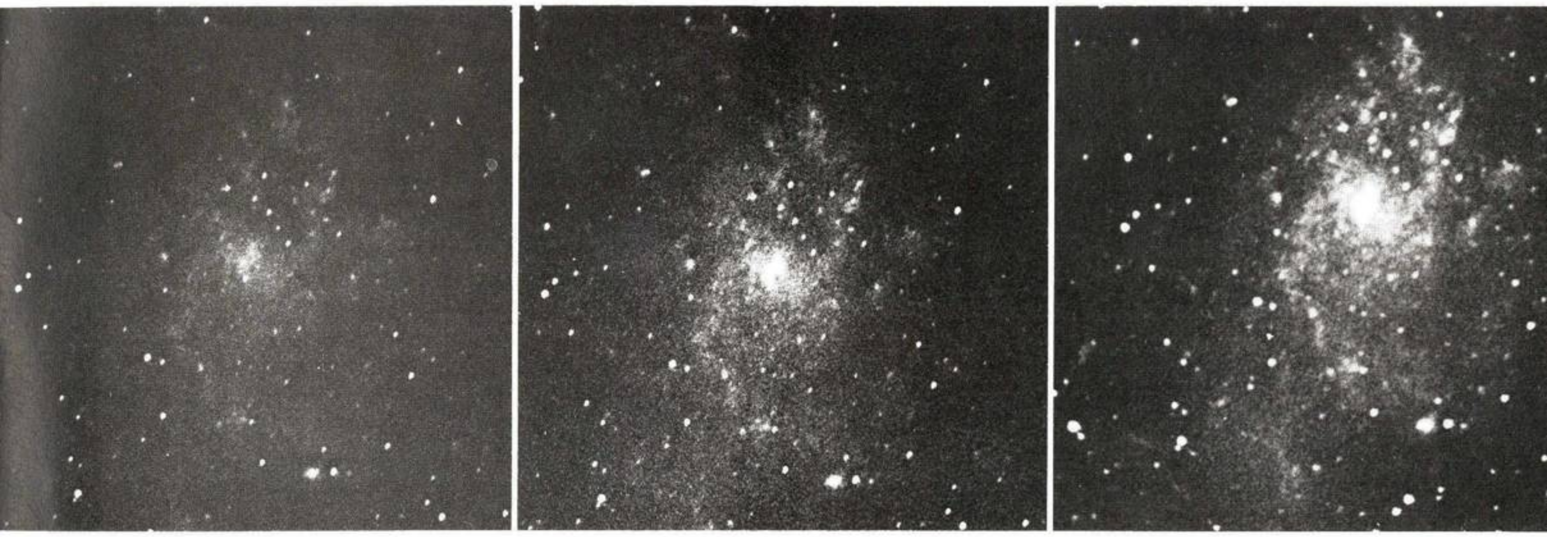
Burning, the reverse of dodging, adds more exposure to areas of the print in order to darken any detail that is too light. Burning is a necessity on full disk photos of the gibbous moon. Without it, a print properly exposed to reveal the dim detail of the terminator will show the rest of the moon as a featureless white disk.

Burning involves using a straight edge or small hole in one of your cardboard tools to isolate the specific area of the print needing additional exposure. You can precisely control the size of the circular area to be burned by moving the cardboard with the small hole up or down relative to the enlarging lens. In this way, you can burn-in additional detail in overexposed areas such as the Trapezium region of the Great Orion nebula, or the inner parts of globular clusters. Again, remember to keep the tool moving during the exposure so that the burned-in area blends smoothly with adjacent areas.

Both burning and dodging take some practice, and even experienced printmakers usually have to make several test prints before they get the best results. If you're making a large print, of course, you don't need to use full sheets of enlarging paper while experimenting to determine the right burning time and movement of the tool. Use smaller pieces of enlarging paper covering a little more than the area requiring this special attention. Once you are sure of your dodging, switch to the full sized paper.

Integration Printing

The biggest problem with high speed films, and especially spectroscopic films, is their coarse grain. Not only is it unattractive, but it tends to hide small detail, faint contrast variations, and dim stars that might otherwise be visible — particularly in objects like nebulae and galaxies.



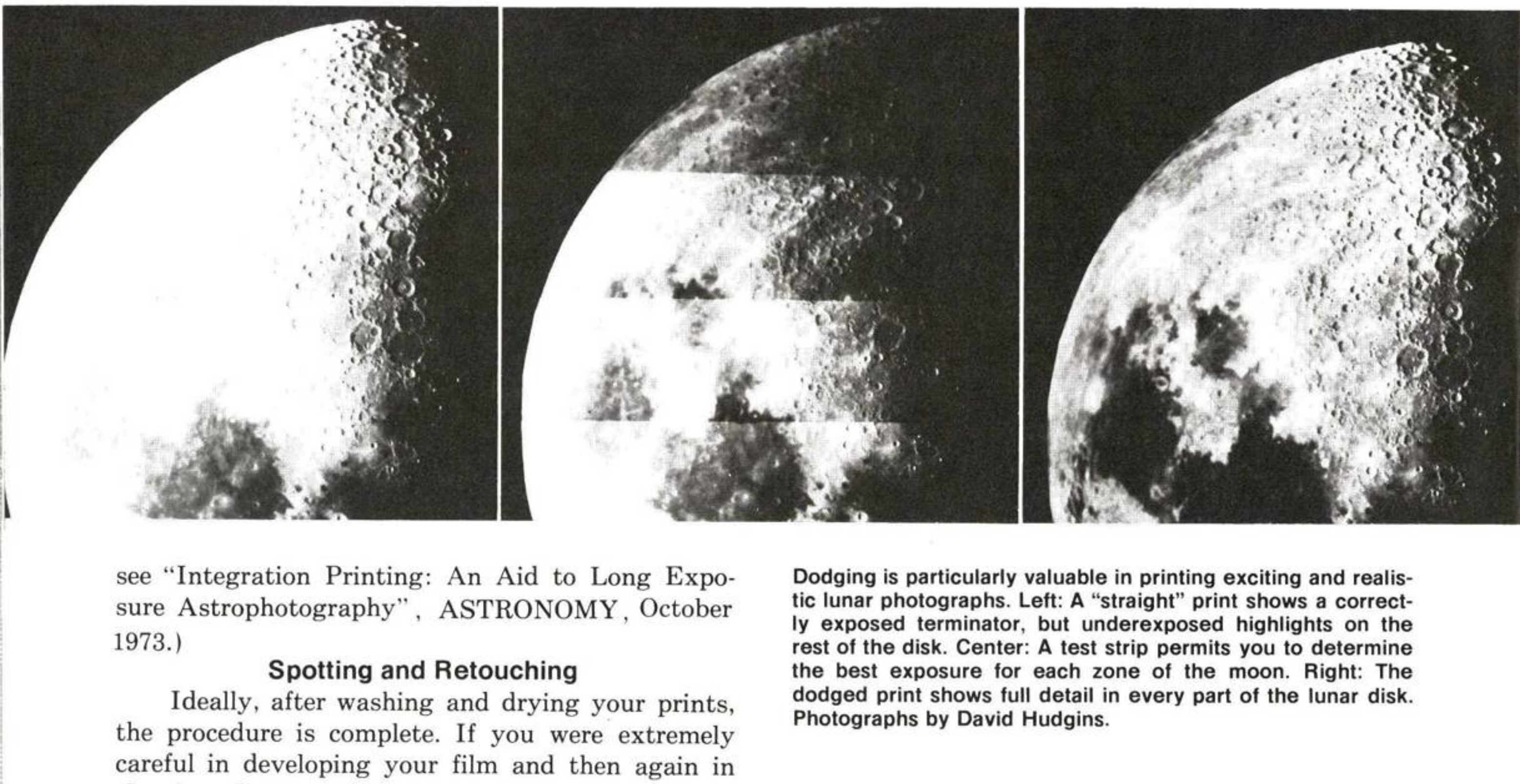
High contrast papers and integration printing can bring out all the details you see on the negatives. Left: A print made on normal contrast paper may not show all the detail the negative contains. This photograph of M-33 was a five minute exposure on 103aE film using a 10 inch f/5.6 Newtonian telescope. Center: A print made on high contrast Brovira grade 6 paper from the same negative shows more detail. Right: An integration print made from four similar negatives combined into one print reduces the graininess of the image. Photographs by David Hudgins.

Integration printing is a method for reducing apparent grain by using several identical negatives to produce a single composite print. The idea is to make short exposures with two or more negatives onto a single piece of photo paper. The multiple exposures "average out" the sharp grain edges and enable detail such as small knots of nebulosity to stand out clearly against a smoother background. The technique is not really difficult; in fact, it can be a lot of fun, especially when you see the striking improvement it can make in your finished pirnt.

To start, you need three or four well-matched negatives of the same object. The fog level of each should be very nearly equal, and each frame itself should be capable of yielding a high quality print. Using more than four frames will reduce grain even further, but will be more work than the additional improvement justifies.

First, tape a piece of thin, opaque cardboard onto your easel so that it completely covers a piece of photo paper, and at the same time can be flipped back so that the projected image from the enlarger can reach the photo paper when you want it to. Place the first frame in the enlarger, and very carefully focus on a piece of exposed photo paper with the cardboard mask flipped out of the way. Once you have done this, don't touch the focus knob again. Now flip down the mask and carefully mark the location of several prominent stars (these marks will enable you to exactly position the easel so that the images of the other frames will exactly coincide with the first). After marking several stars, determine the normal printing exposure using a single negative. The idea is to divide this exposure among the number of frames you are using so that each contributes equally to the final print. To compensate for a number of photographic effects, these "partial" exposures must be increased a little to get the same result as a single exposure. After dividing the normal exposure time by the number of frames, add an additional 25 percent to the first exposure and 10 percent to each subsequent exposure. Assume, for example, you have four good frames and the proper exposure with any one of them is 40 seconds; for integration printing, your first exposure would be 12 to 13 seconds, followed by 11 second exposures for the remaining three frames. To get the best results, be sure to use an enlarging paper at least one contrast grade higher than normal — usually a #4 or #5 works best.

With the first frame still in the enlarger, turn out the room lights and place a sheet of enlarging paper under the cardboard mask. It is important that the paper never move during the multiple exposures, so it is a good idea to tape two edges carefully to the easel. With the protective mask in place, turn on the enlarger and carefully line up the projected star images with your reference marks. Now stop the enlarger lens down as in the test exposure, flip back the mask, and make the first partial exposure. Next, replace the mask, put in the second frame, and line up the reference stars; then remove the mask and make your second partial exposure. Repeat this sequence for each of the remaining frames, and then develop the print in the normal manner. If you were careful in getting each exposure lined up, your final print will have sharp star images, much finer grain and better detail throughout the photo. (For additional information, see "Integration Printing: An Aid to Long Exposure Astrophotography", ASTRONOMY, October 1973.)



Dodging is particularly valuable in printing exciting and realistic lunar photographs. Left: A "straight" print shows a correctly exposed terminator, but underexposed highlights on the rest of the disk. Center: A test strip permits you to determine the best exposure for each zone of the moon. Right: The dodged print shows full detail in every part of the lunar disk. Photographs by David Hudgins.

Spotting and Retouching

Ideally, after washing and drying your prints, the procedure is complete. If you were extremely careful in developing your film and then again in cleaning the negative, your prints may not need any additional work. Chances are, however, that a few extra dust "stars" and white lint squiggles will appear on your print, detracting from the beauty of the photo. Those spots and squiggles are glaringly apparent on astrophotos because they stand out clearly against a dark background. The processes of removing these defects are called *spotting* and *retouching*. Any print that you plan to display or keep permanently in an album is worth the few extra minutes needed to bring it as close as possible to perfection.

Spotting is the more common and less controversial of the two print finishing techniques. It involves using a fine brush and black dye to cover up white dust spots or lint squiggles. For less than $2, Kodak sells a kit of spotting dyes which are easily used — almost exactly like water colors.

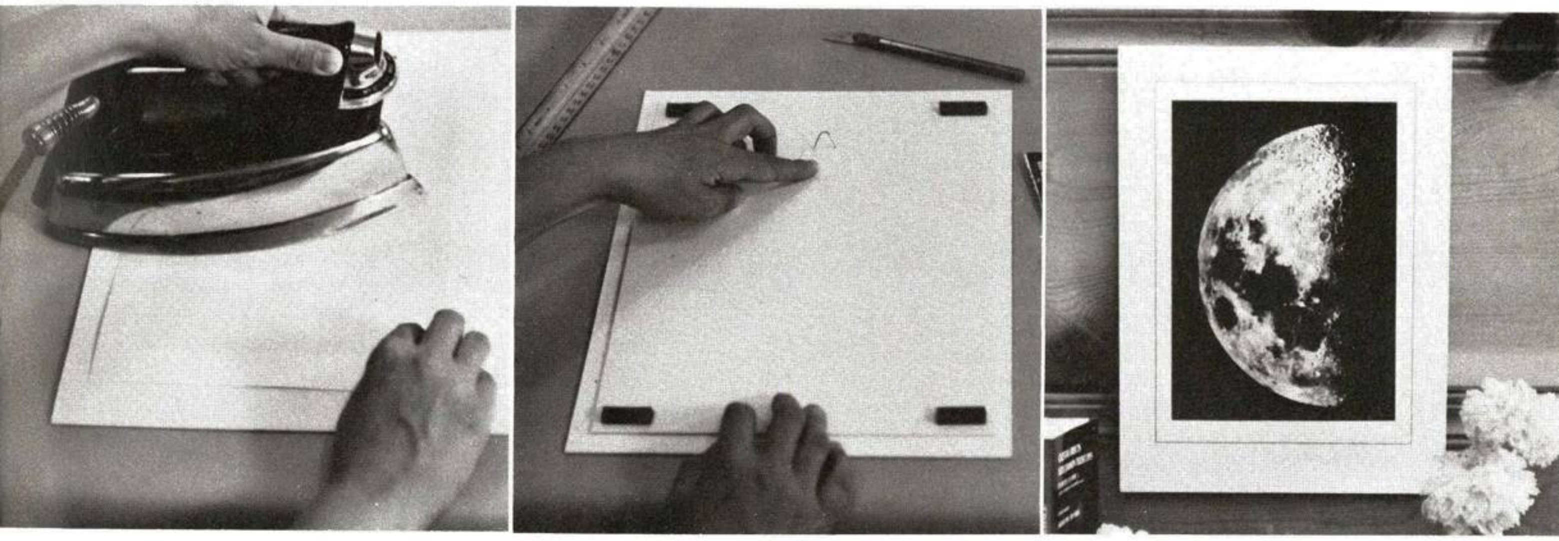
Good spotting requires a lot of light and a magnifying glass. Be sure to apply the dye only to the white spot and not to the adjacent area, in order to avoid a darker ring around each squiggle you are trying to cover. It is usually best to apply two or three coats to a spot in order to more exactly match the density of the surrounding area. This is quite easy with most astrophotos — at least on the dark sky background where dust marks are the most frequent problems.

Despite the processing advantages of RC papers (see "Printing Your Astrophotographs, Part 1: Basic Printmaking", December 1976), they are more difficult to spot than conventional fiber based papers. The emulsion of RC papers does not readily absorb spotting dyes, especially if they were processed in a fixer with a hardening agent in it. This problem can be minimized, however, by adding a little acidity to the dye in order to soften the emulsion. Instead of using plain water to wet your spotting brush, try the following solution: Add three drops of acid stop bath concentrate and one drop of a setting agent such as Photo-Flo to eight ounces (250ml) of water. This solution enables the dye to be applied smoothly to the emulsion of RC papers. But it still may not be fully absorbed, as the dye forms a somewhat fragile coating over the spot rather than really eliminating it. For photos with extremely dark backgrounds, like planetary shots, a black fiber tipped pen may cover white dust specks on RC papers better than spotting dyes.

In astrophotography, retouching is a touchy subject. Every amateur must recognize what every professional astronomer already knows — that regardless of its beauty, no astronomical photograph is worth the paper it's printed on if it isn't totally and absolutely honest. Don't give in to the temptation to touch-up that comet's tail or add a little structure to the equatorial belts on Jupiter. In astronomical photography, both spotting and retouching must be limited to removing unavoidable defects such as dust specks, lint shadows, pinholes and scratches. While careful mixing of the black and white dyes should enable you to match any tone on the print, it is best to start with the cleanest possible negative to minimize later touch-up work.

Displaying Astrophotos

Once you discover the fun of doing your own darkroom work, you will probably soon find yourself overrun with astrophotos. They pile up on tables and odd corners of the darkroom, fatten envelopes, fill drawers, and generally begin to suggest an ability to reproduce entirely on their own. Your prints will soon become lost or damaged without some organization. Since part of the joy of astrophotography is showing off your work, you should give some thought to how to present your best photos to the world (and yourself).



Dry mounting steps are easy to do at home. Left: After tacking the tissue in place with the tip of an iron, the print is covered with a sheet of clean paper. Heat and pressure from the iron affix the print to the mountboard. Center: Attach a hanger and spacers to the back of the print. Right: You'll be proud of your prints when they hang on the wall in an attractive matteboard. Photographs by David Hudgins.

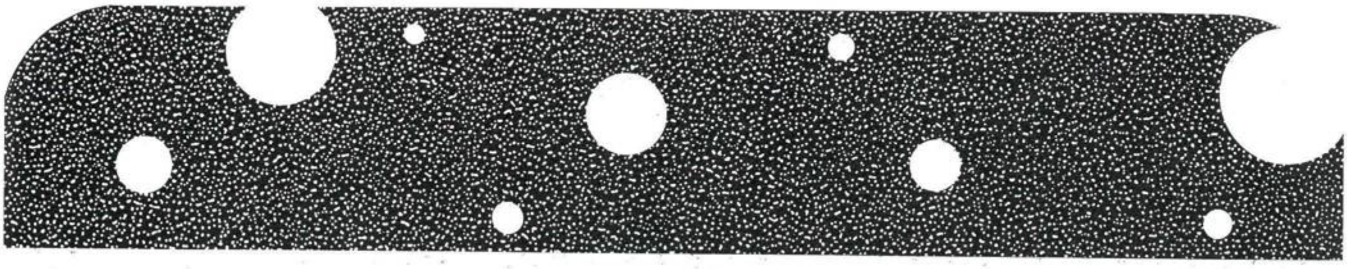
Regular photo albums work well for small prints. The more expensive types have self-adhesive features, but you may find that glue backed photo corners or one of the special mounting cements are more practical. Double sided gummed tape can be used to mount RC papers, but they can eventually damage regular papers; avoid common glues and cements on any photo paper. If you like albums, you can insert your 8 x 10 inch prints back-to-back in plastic sleeves that fit standard notebooks.

Some astrophotographers simply store their prints in the cardboard boxes that their photo papers came in. Your photos could be filed chronologically, or by subject matter. When someone wants to see your work, just hand them a box.

Every astrophotographer eventually has a number of favorite shots — the best work which should be displayed for continued enjoyment. One of the best ways is to "dry mount" your photos for wall hangings. Mounting enables you to permanently attach any photo to illustration board with "dry mounting tissue" available from art supply and photo shops. The waxy tissue is placed between the photo and the backing; when heat is applied, the wax melts, forming a permanent bond. A special heating press is needed for large prints, but a regular laundry iron will do for prints up to 8 x 10 inches. Cut the tissue to the exact dimensions of your print, and "tack" it onto the back of the photo using the slightly warm iron. Position the photo on the mounting board and put a clean sheet of bond paper over the print surface to prevent damage. Place the warm iron in the center of the photo, and move it smoothly out to each edge (this helps prevent bubbles from forming). After mounting, attach one of the glue-on hooks available at the hardware store. Next, stick on a short piece of adhesive foam (commonly used for weatherstripping) in each corner. Your mounted print will now hang beautifully on the wall.

So that's it! Perfecting your darkroom techniques to a level of mastery naturally requires time and persistence. Fortunately, the whole learning process is great fun — particularly as you compare your old prints made by the drugstore to the crisp and sparkling enlargements you've made yourself.

Editor's Note: Additional articles on specialized printing techniques and their applications in astrophotography will appear in the next few months.



Chinese Cosmology

by
John Gribbin

The discovery of pulsars — fast-spinning neutron star relics of past supernova explosions — encouraged astronomers in the late 1960s and early 1970s to seek historical records of supernovae in an attempt to relate the recorded events to known pulsars. In this search, ancient observational records of Chinese astronomers — going back thousands of years, and long recognized as accurate — have proved invaluable to modern astronomers.

But it is one thing to observe and note the appearance of phenomena in the heavens — however accurately — and quite another to interpret the observations. We might assume that while the Chinese were good at observing, they didn't perceive what their observations meant. That attitude, however, would be thoroughly unjustified. Chinese astronomer/philosophers — who held high, well-respected positions in ancient times, unlike their Western counterparts — developed complete theories of the universe in their own science of cosmology. Some aspects of that cosmology were forerunners of the concepts of modern relativistic cosmology.

Looking back over the past 2,000 years of Chinese cosmology, it is interesting to note that from earliest times, varying theories of the universe have existed. Although "flat Earthers" certainly vocalized their ideas, the concept of a celestial sphere surrounding a spherical Earth existed as an alternate hypothesis. The situation may have been very much like the state of Western cosmology in the 1950s and 1960s, when both the steady state and big bang theories of the universe were popular. From the fourth century B.C. onward, followers of both the round and flat Earth theories could be found, no doubt arguing their causes like the Fred Hoyles and Martin Ryles of today. And, of course, there were other schools of thought — splinter groups diverging from the mainstream of debate.

The Chinese respected their learned men and gave them important positions and titles. Here, venerable observers of the skies, using little more than their eyes and minds, watch and study. One of the more important observations they made — at least in the view of modern astronomers — was the appearance of "guest stars" that we call novae and supernovae. In 1054 A.D., in the western constellation the Bull (the Chinese cock), they saw the supernova that gave rise to the Crab nebula and pulsar. Painting by Patty Heid.

In looking for parallels between ancient Chinese and modern cosmology, it is to one of these splinter groups that we must turn: the Hsüan Yeh theory of the universe, developed about 2,000 years ago. Although his records were lost, Hsüan Yeh's teachings came to us secondhand through the written remembrances of a librarian of a later era, Chi Meng: "They said that the heavens were empty and void of substance....The sun and moon and the company of stars float freely in the empty space, moving or standing still. All are condensed vapor." This remarkable description was written in the third century A.D., reporting the work of a master already dead for two or three hundred years! Hsüan Yeh's teachings were not forgotten, and reappeared in the later works of other great Chinese astronomers.

Yü Hsi, the discoverer of the precession of the equinoxes, wrote in 336 A.D., "I think that the heavens are infinitely high, and that the space below the Earth is unfathomably deep". These ideas were almost 1,500 years ahead of those in the West, where until the 17th century, the concept of the

Aristotelian "crystal spheres" — reinforced by its status as religious dogma — reigned virtually unchallenged. Intriguingly, and perhaps not entirely coincidentally, the crystal sphere concept was shattered and Western cosmology began to develop as a science just as news of Chinese mathematics and astronomy began to reach the West.

Jesuits who visited China at the end of the 16th and beginning of the 17th centuries "took" their religious dogma with them. While it is possible that the news from China catalyzed the development of cosmological thought in the West, it is certain that the stifling blanket of this religious dogma (the West's contribution to China) halted the progress of Chinese cosmological thought to the extent that it finally "recovered" only during this century.

In messages sent home to Europe by visitors to China, Chinese philosophers were ridiculed for their stupidity and barbarism — sometimes at such length that a modern reader might wonder if the writers were not using this as a "reverse" ploy to spread the news, thus avoiding the possible wrath of their superiors. Matteo Ricci listed several of these "absurdities" in letters written late in the 16th century, but his comments leave us wondering with whom he truly sympathized: "They say that there is only one sky and not ten skies; that it is empty and not solid. The stars are supposed to move in the void, instead of being attached to the firmament.... Where we say there is air between the spheres, they affirm there is a void." This news reached the West during Galileo's time, and though presented as "absurd", many Westerners analyzed the information objectively.

In the West, perhaps spurred by this news, science began to break away from religion. The Jesuits, however, continued to strictly censor Western news which reached China, keeping the ideas of Copernicus and others secret. The result was that the mainstream of cosmological thought shifted completely from East to West.

Nevertheless, Western cosmological thought still did not surpass that of the East. It wasn't until the 20th century that Western cosmologists determined that galaxies were "island universes", and that the Milky Way was far from being all there was in space. As long ago as the 13th century, Têngu Mu described the plurality of worlds in these terms: "Heaven and Earth are large, yet in the whole of empty space they are but as a small grain of rice ....Empty space is like a kingdom and heaven and Earth no more than a single individual person in that kingdom. How unreasonable it would be to suppose that besides the heaven and Earth we can see, there are no other heavens and no other Earths." To turn Têngu Mu's observation into a modern statement, it is necessary only to substitute "Milky Way" or "galaxy" for "heaven".

By the 18th century, at least one Western cosmologist — English astronomer Thomas Wright — had come very close to realizing that the Milky Way was a lens shaped aggregation of stars; his work was published in 1750 (**An Original Theory, or New Hypothesis of the Universe**). Charles Whitney later wrote that Wright's book "was largely ignored by his contemporaries, perhaps because they did not know what to make of it." If Wright had known about the teachings of Têngu Mu, Western cosmology might have leapt ahead 200 years to the concept of island universes. But such a concept would probably never have been accepted until telescopes were able to provide conclusive evidence in its favor.

The Chinese had a better grasp of space and time than anyone in the West in pre-Hubble days. Even in the 18th century, the official estimate of the age of the universe was a mere few thousand years — based on the Anglican Archbishop James Ussher's rather imaginative interpretation of the Bible that creation occurred at 8 p.m. on Oct. 22, 4004 B.C. But fully 10 centuries before Ussher's estimate was made, the Chinese placed the moment of the most recent "conjunction" of the cyclical universe — a Buddhist concept — at 100 million years in the past. While 150 times smaller than today's estimates, it is indicative of a much better grasp of reality than that showed by 18th century Western theologians.

A quote of a 120 B.C. text in Joseph Needham's book, **Science and Civilization in China**, demonstrates how complete the Chinese grasp of space and time was even then: "All the time that has passed from antiquity until now is called chou; all the space in every direction, above and below, is called yü." From this, we might translate the Chinese expression yü-chou, generally understood as "the universe", more literally as "space-time" — a 2,000 year preview of Einstein's concept of the oneness of space and time! Even in 300 B.C., the Mohists stated: "Movement in space requires duration .... In movement, the motion of an observer must first be from what is nearer and afterward to what is farther. The near and far constitute space. The earlier and later constitute duration."

Of course, these passages support the idea that Chinese cosmology may have preceded modern Western cosmology. By choosing other texts, it is possible to highlight absurdities in the philosophy of these ancient cosmologists, just as Ricci did four centuries ago.

Parallels between Chinese cosmology and relativity should not be drawn too closely. We must remember that theories are accepted only when society is ready for them (in this respect, Einstein was certainly lucky). But the openmindedness of the old Chinese philosophers is striking. In being prepared to consider new theories, they certainly hit on one close to modern thought — even if it was not appreciated and could not be proven at the time.

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GAZER'S GAZETTE

Exploring the Milky Way: Part 2

by
Richard Berry

To many city-raised observers, the first view of the winter sky in the country comes as a surprise. Warm weather makes the summer sky familiar to campers or vacationers; the sight usually provokes awed thoughts of "What have I been missing?" But subzero temperatures, winter skies cloudy for weeks on end, and vacations taken exclusively in summer combine to keep many city-bred people from ever seeing the glorious sights of Orion, Taurus and Canis Major in the winter sky, with the delicate stellar tracery of the Milky Way almost flowing across the sky beside them.

In winter, the Milky Way runs through Cassiopeia, Perseus, Auriga, Taurus, part of Orion, Monoceros, and (for most of us) disappears below the horizon around the southern end of Canis Major and northern Puppis. Although stars seem to shine at their brightest in the winter sky, the winter Milky Way lacks the brilliance of summer's. Instead of the starclouds and dark rifts that characterize the summer Milky Way, winter provides a long look deep into a smooth band of stars and star clusters.

As we look away from the galactic nucleus (into the galactic "boondocks"), our view includes the faint outer spiral arms of the galaxy. In fact, the galactic anticenter (the direction directly away from the center) lies near the Auriga/Taurus border. But the view away from the galactic center is by no means a dull one. The outer arms of spiral galaxies are rich in open clusters, huge hydrogen gas clouds, and regions of star formation — and the Milky Way galaxy is no exception.

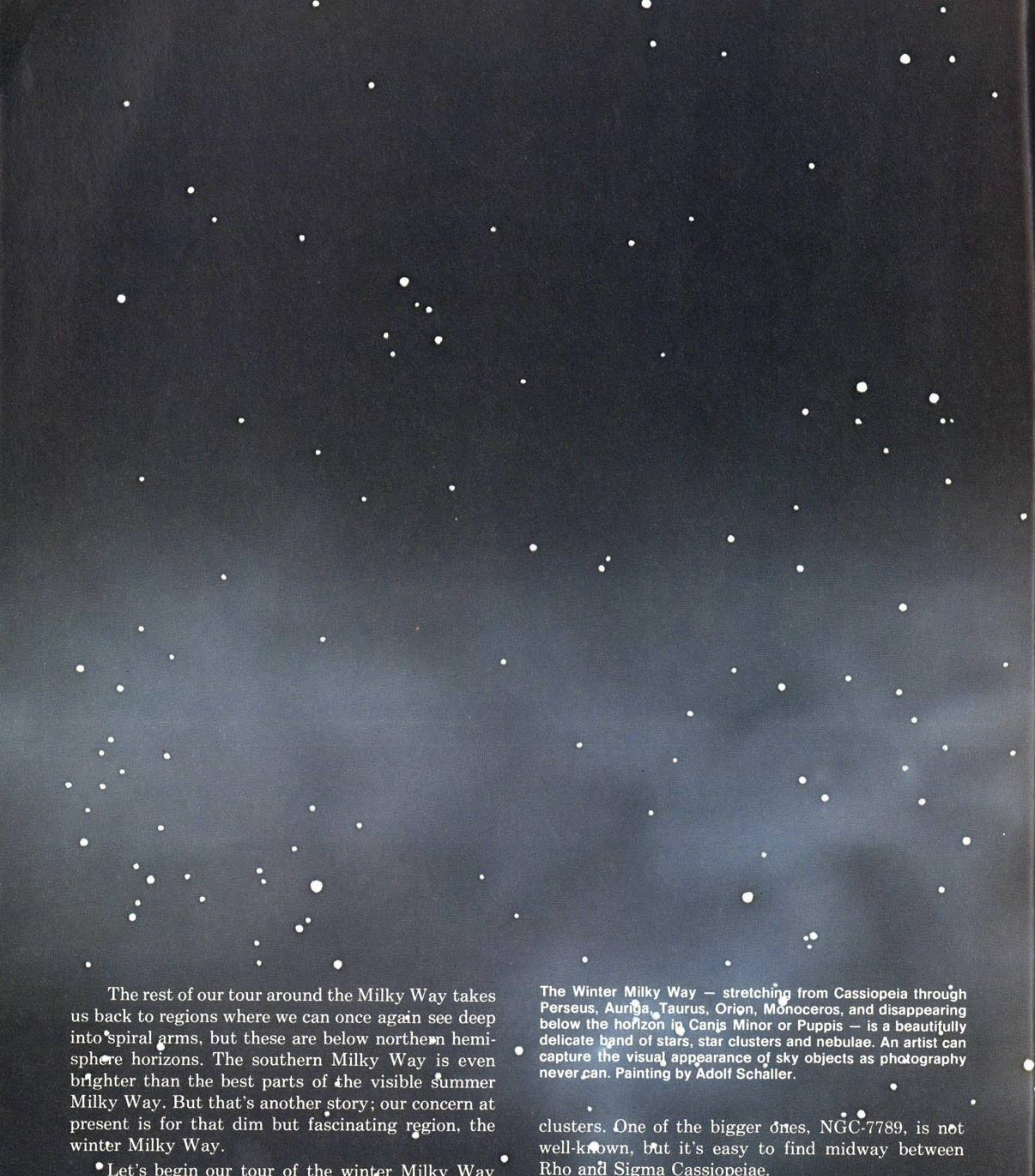
Haze and light pollution often remove much of the splendor from this delicate region of the sky. In particular, many observers in suburbs or small towns find that, as they follow the Milky Way north from Cygnus, it fades into oblivion in Cassiopeia. But the Milky Way doesn't really fade away — you just need a good sky to see it.

What parts of our galaxy lie in the direction that rises high in northern winter skies? When we look toward the galactic center, we see dust and obscuring material that's draped along the interior edge of the spiral arm in which our sun is located: the Cygnus arm. Above and below these dust lanes (the familiar Great Rift), we can see inward to the Sagittarius arm — the arm of the galaxy that lies next inward. As we move along the plane of the Milky Way toward Cygnus, we look farther into the interior of our spiral arm. In Cygnus itself, our view is blocked by relatively nearby dust clouds, such as the ones around the North America nebula.

When we swing still farther along the galaxy, we eventually reach the anticenter region, directly away from the nucleus. At this point, we're no longer looking through deep layers of stars; instead, our view is out the backside of our arm, across a gap, and into the spiral arm that lies next outward — the Perseus arm. Along the inside edge of that arm lie irregular patches of dust, obscuring some parts of it. The star clusters in the Perseus arm are much farther from us, and therefore dim. Outer arms of most spiral galaxies — including our own — are fainter, contain fewer stars, and are more ragged and ill-defined than the inner arms. Thus the brightness of the Milky Way, through the winter constellations Perseus, Auriga and Taurus, is low.

Further sweeping eventually points us in the direction of Orion, into a common spiral arm feature: an irregular bit of semidetached arm called a spur. In this little interarm spur lies an incredibly active region of stellar birth, including the Orion nebula and all the hot, young blue stars and nebulae associated with it.

No starclouds or enormous dark rifts are found in the region of our galaxy opposite the center. Instead, open clusters (such as M-35 and IC-443 in Gemini, and the Auriga clusters) and a smooth, rich star background are characteristic of the winter Milky Way. Bottom: The red region NGC-2244 (the Rosette nebula) and NGC-2264 (above and to the left) are both H-II regions located in Monoceros. Betelgeuse, the shoulder star of Orion, is at the extreme right. Both shots are 30 minute exposures. Photographs by Robert Burnham.



The Winter Milky Way — stretching from Cassiopeia through Perseus, Auriga, Taurus, Orion, Monoceros, and disappearing below the horizon in Canis Minor or Puppis — is a beautifully delicate band of stars, star clusters and nebulae. An artist can capture the visual appearance of sky objects as photography never can. Painting by Adolf Schaller.

The rest of our tour around the Milky Way takes us back to regions where we can once again see deep into spiral arms, but these are below northern hemisphere horizons. The southern Milky Way is even brighter than the best parts of the visible summer Milky Way. But that's another story; our concern at present is for that dim but fascinating region, the winter Milky Way.

Let's begin our tour of the winter Milky Way in Cassiopeia, near the northernmost part of the galactic circle. The Milky Way is about 27 degrees from the pole at its closest, not far from Gamma Cassiopeiae, the middle star in the "W". Gamma, itself, is an interesting star, having changed brightness irregularly over the past few centuries. Near Gamma are two small H-II regions; these nebulae are almost impossible to see, but not difficult to photograph. Cassiopeia abounds in faint open clusters. One of the bigger ones, NGC-7789, is not well-known, but it's easy to find midway between Rho and Sigma Cassiopeiae.

A short distance down the galactic circle, in Perseus, we find the well-known Double Cluster, NGC-869 and NGC-884, which is visible with no optical aid at all. Seen in a small telescope at around 40 power, these twin clusters are a memorable pair of objects. In large telescopes, their beauty is often diluted; the clusters overfill the field, and the dark space that makes a cluster *look* like a cluster is lost. Just five degrees north of the Double Cluster is a

region rich in faint clusters and gas. Visually, you can spot only the clusters, but the extensive gas clouds in this region show as reddish stains if you photograph the area on color slides. Virtually any optical aid can be used to explore these starfields, from the lowliest opera glasses to 7x50 binoculars, little 16 power RFTs, giant binoculars, and of course, conventional telescopes used at very low powers. Cluster filled regions are a joy to sweep without a map, just for the fun of seeing something you didn't expect to find; they're also great fields to observe with a good star atlas, as you try to find every object plotted.

While the Milky Way shines weakly in Cassiopeia, it almost fades out completely just past the Double Cluster, as if enormous dark clouds obscure a 20 degree section of stars. Near this dark hole (which resembles a transplanted section of the Great Rift in Cygnus) lies a spectacular swarm of bright stars — several dozen in all — between Alpha and Delta Persei. As you sweep across this oval of stars with binoculars, you'll see how truly brilliant this area is compared to adjacent regions.

The mini-Rift is overlaid by nearer, darker dust clouds, but they are only a beginning. As we move farther around the galactic circle, we'll find more and more dust clouds. Perseus is clean by comparison to Taurus. Between Epsilon and Xi Persei lie two interesting objects, both elongated in the galactic plane: an unnamed dark cloud and an H-II region known as the California nebula. (Many dust clouds in the galaxy are elongated, presumably along the galactic magnetic field.) By the time we reach Taurus, the dark nebulae are so large, dark and conspicuous that they can be seen by eye, or easily recorded with small cameras. But before arriving at

Taurus, the Milky Way passes through a brilliant, unobscured region in Auriga.

The southern end of the pentagon figure forming the Auriga asterism is filled with stars and clusters. Every observer is familiar with M-36, M-37 and M-38, but how many know that these three open clusters lie very near the galactic plane, close to the anticenter? The three clusters are fun to compare with each other because they are all different. Nearby is a nebula (IC-405) surrounding AE Aurigae — a star moving at high speed away from the Orion region.

The background Milky Way in Auriga is remarkably smooth and homogenous on the north side of the galactic circle, where stars fade away smoothly. But on the south, in Taurus, the dark nebulae cause an abrupt brightness dropoff. The southern Perseus/Taurus area has three great arcs of dark nebula: one near the California nebula, another between Beta and Zeta Tauri, and a third, far-flung cloud that reaches out toward the Pleiades. The absence of the Milky Way glow allows you to distinguish these clouds by eye, and on photographs you'll notice a marked absence of stars in these areas. Obviously, to see dark nebulae such as these, you'll need a superbly clear, dark sky. Two faint but beautiful clusters in this region, NGC-1646 and NGC-1746, are easily visible in binoculars.

Two of the most famous star clusters — the Hyades and the Pleiades — are in Taurus. The Hyades cluster covers a five degree circle of sky. The brightest stars in the Hyades are arranged in a rough "V" shape, but the cluster is essentially circular. The Hyades stars are "standard candles" whose distance can be measured precisely; they are among the fundamental objects that astronomers use in determining the distance to very distant stars. The Pleiades stars form a different standard — one for very young clusters.

The Pleiades, like the Hyades, comprise a naked eye cluster, but more condensed. Visually, the number of Pleiades you can see gives a rough measure of your eyesight. Five or six is fair; a dozen is quite extraordinary. But whether you can see many or just a few by naked eye, binoculars or a small telescope make them one of the loveliest sights in the whole sky. The Pleiades are surrounded with reflection nebulae (presumably of the same dusty material that engulfs the rest of Taurus), illuminated by the light from the bright stars in the cluster. The nebula is brightest around the star Merope. If you block the star, you can see the nebula with a 10 inch telescope under good conditions.

The Gemini twins get their feet into the Milky Way with the bright cluster M-35 (another one of those "Gee, I didn't know *that* was a Milky Way cluster" objects) and the beautiful H-II region, IC-443. (Getting off the "beaten track", the Beehive cluster to the east in Cancer — though not actually located in the bright band of the Milky Way — is another object that rightfully belongs in our tour of the galaxy.)

After passing through dusty, gassy Perseus and Taurus, the Milky Way broadens and presents a smooth, uneventful face: Nowhere else in the entire galactic circle are stars so regularly and evenly distributed. This is the result of our view farther into the Cygnus arm. But unlike the Milky Way in Cygnus, Monoceros does not feature heavy clouds of absorbing material to create rifts and irregular starclouds. This region is not dull — quite the contary — for here the Orion spur leaves the Cygnus arm, pointing outward at a crazy angle. Bright blue stars, nebulae, dust clouds, and regions of star formation — all activity associated with the formation of new stars from gas — lie in the Orion spur. Our vantage point gives us an end-on look into the spur. Some 1,500 light-years (460 parsecs) into it lies the Orion complex, containing the Orion nebula. While the entire Orion nebula is at best a degree in diameter, the Orion complex is much larger; it covers most of the figure of Orion, then spreading and extending deep into neighboring Eridanus, with a few of its faint filaments glowing at H-alpha wavelengths.

In Monoceros, two well-known H-II regions — the Rosette nebula and NGC-2264, which contains the Cone nebula — are a disappointment to the naked eye astronomer. The light they emit is largely red light, to which the eye is barely sensitive, although the camera is not. Thus these nebulae are famous largely from their pictures — especially the Cone, which is the subject of a dramatic picture taken with the 200 inch Palomar telescope. The Rosette, on the other hand, is an easy target with a telephoto lens. Both objects contain a star cluster that illuminates and excites the dust and gas, but neither cluster is particularly impressive in a telescope.

As the Milky Way gets down to Canis Major and Puppis, we are again looking far down the length of the Cygnus spiral arm. More depth into the arm means many more bright clusters: Messier lists only four, but there are literally dozens of easy ones in this part of the sky. M-41 is the best, located four degrees directly south of Sirius; it has a bright reddish star near its center. But the richness of this field offers an excellent opportunity to "knock off" four Messiers and a dozen NGC objects in a short time — even one night. In fact, the field is so rich here that you can sweep with binoculars or an RFT and find clusters without even searching. We'll leave it to you to pick them out yourself.

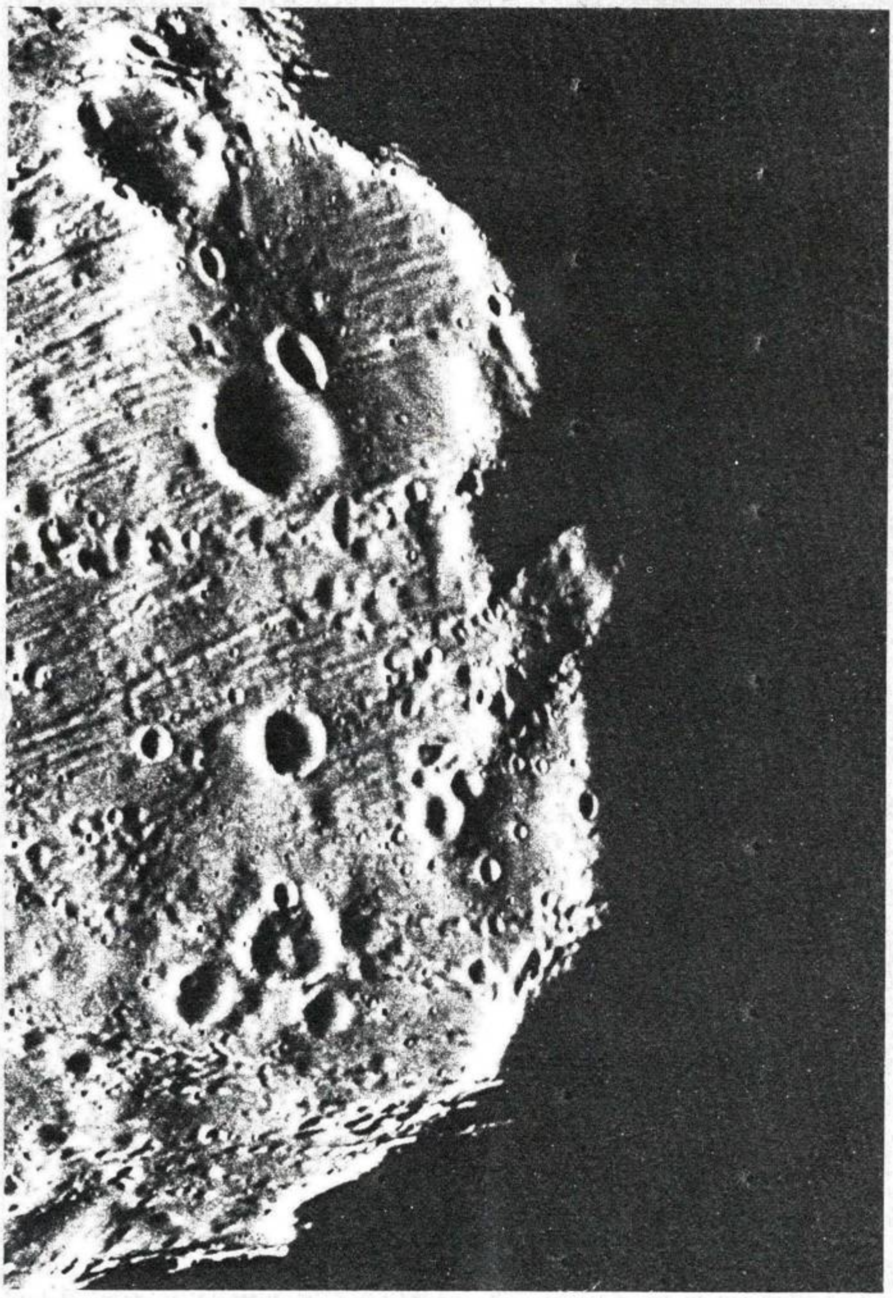
Man's inside-out view of his own galaxy is by no means complete. The shapes of the spiral arms can be determined only with great difficulty, including laborious measurements on the so-called spiral arm tracers such as H-II regions and bright blue stars. But the picture of space they yield gives us a deeper appreciation of the readily visible structures that we can see on any clear, dark night.

ASTRO-NEWS

Latest News From the World of Astronomy

Crater Chains on Phobos

Viking has discovered another mystery in the most unexpected place — on one of the two small Martian moons. Mariner 9's mapping of both Phobos (12x14x17 miles, or 20x23x28 kilometers) and Deimos (6x7x10 miles or 10x12x16 kilometers) showed many craters and left most investigators with the impression that they were merely rocky chunks that bore the scars of meteorite impacts. There was a puzzling feature on Phobos that a few analysts noticed but, without better data, could say little about.



NASA photograph

At the limit of resolution were a few small crater pits that seemed to align in one or two chains. This was unusual, because crater chains on the moon are traditionally explained as volcanic pits — small eruption sites strung along fracture lines. Yet Phobos apparently is too small to generate heat and conventional volcanic activity.

Viking's high resolution photos have revealed that the crater chains are real and part of an extensive system of parallel grooves, a few hundred yards wide. There may be a tendency for the grooves to lie parallel to the direction of the satellite's orbital motion, although there appear to be several swarms with somewhat different orientations. Scientists are at a loss to explain them. Theories being discussed include: grooves left by much smaller satellite debris also orbiting Mars (though the grooves seem to follow contours of Phobos' surface too closely for this to be tenable); fractures radiating from an impact crater not yet recognized (perhaps on the side of Phobos still poorly photographed), or fractures created in the body of the Martian satellite when it was part of a hypothetical larger body that spawned both Martian moons, perhaps during a catastrophic impact.

15 Years of Space

In 1965, space authorities from NASA and the Soviet Academy of Sciences joined to form the U.S.-USSR Joint Editorial Board on Space Biology and Medicine. Results of their efforts were recently published by the U.S. Government Printing Office in the three volume edition, Foundations of Space Biology and Medicine.

The work summarizes the first 15 years of man's endeavors in space. Of the 45 chapters, 19 were written by American authors, 20 by the Soviets, and six by members of both countries' scientific communities.

Apollo Asteroid Passes Unusually Close to Earth

One of the closest approaches of an asteroid to Earth ever recorded took place on Oct. 20, 1976, when an object designated 1976UA passed within 750,000 miles of our planet — the nearest flyby of any minor planet since Hermes came within 500,000 miles in 1937.

1976UA is a very small asteroid — probably only 1/4 mile (.4km) in diameter. Thus it is intermediate in size between Hermes and the third-closest "Earthgrazer", Adonis, which passed in 1936. It orbits the sun at an average distance of about 78,000,000 miles, with an orbital period of only nine months.

Asteroids like 1976UA that pass very close to Earth are known as Apollo asteroids, after the first such object discovered. All those known have been detected only by the streaks their reflected light leaves on photographic plates; none is big enough to study with Earth based telescopes.

While 1976UA is interesting in itself, the story of its discovery is also interesting, as well as amusing. On the night of Oct. 24-25, 1976, William Sebok (a graduate student at Caltech) was photographing galaxies with the 48 inch Schmidt telescope at Mount Palomar. At the same time, Dr. Eleanor Helin and two students were using the 18 inch Palomar Schmidt telescope, in Helin's continuing program of searching for Apollo asteroids.

The next day, a puzzled Sebok showed a fast moving streak on one of his plates to Helin and asked her to identify what he had found. She checked her plates and found a streak similar to the one on Sebok's. That night, Sebok and Helin photographed the object again; on Oct. 26, they sent all their plates to Pasadena for measurement and orbital calculation.

The measurements were made by S.J. Bus; on his way down to the measuring engine, Bus met Charles Kowal (discoverer of Jupiter XIII), who held out a plate and commented on the fast moving streak he had found! Bus took Kowal's plate along, and his orbital calculations and measurements showed that it was the same object discovered a few days later by Sebok and Helin.

The problem, of course, is who to attribute 1976UA's discovery to. Kowal was the first to photograph the object, Sebok was first to find it, and Helin first identified it — not to mention Bus, who determined the measurements of orbit. Brian G. Marsden of the Smithsonian Astrophysical Observatory remarks that he was "deliberately vague" in identifying the discoverer on IAU circular no. 2999, where 1976UA's discovery was reported. A situation like this points up the extreme difficulty of attributing many modern discoveries.

Nova Cygni Possible Single Star

Just as astronomers seemed to have established that optical novae (and x-ray novae) occur in binary systems, a new theory has been proposed that Nova Cygni 1975, the brightest nova in 33 years, was a single star outburst. This interpretation (published in the **Astrophysical Journal Letters**) is not really contradictory, however, because Nova Cygni was a very unusual optical nova. In fact, its rise and fall in light was more like that of a speeded-up supernova, which is a far more catastrophic eruption of a single star.

Nova Cygni reached a maximum magnitude of 1.8 at the end of August 1975, setting a record for the greatest brightness range of any nova. Since no star is visible in its position in the Palomar Sky Survey plates, the increase in brilliance must have been at least 20 magnitudes. However, observations indicate that only about 10^{-4} solar masses were ejected in the outburst, which is in keeping with the behavior of a nova rather than a supernova. Consequently Nova Cygni is now being interpreted as a single star undergoing a thin shell thermonuclear explosion.

The observed light curve of the nova matches that calculated for a thermonuclear runaway and ejection of mass in a hydrogen-rich envelope on a single white dwarf. In normal binary novae, the hydrogen envelope that ignites is gravitationally transferred from the companion star. It is the presence of this companion that seems to affect the light curve of the nova during its subsequent eruption, producing the characteristic kinks and spikes that are missing in the light curve of Nova Cygni 1975. But without a nearby secondary star to feed it, where did the hydrogen envelope for Nova Cygni come from?

Calculations show that about 1 white dwarf in 100 could sweep up sufficient mass from interstellar clouds during its lifetime. All the conditions necessary for a nova eruption could likely be realized on an isolated white dwarf, making the association of nova-like events with close binary systems not so unusual. Therefore, this single star hypothesis could offer an attractive explanation for Nova Cygni 1975.

Soviet Reverses Position

Soviet astronomer I. Shklovsky, co-author with Carl Sagan of **Intelligent Life in the Universe**, has apparently changed his mind about the existence of extraterrestrial intelligent civilizations. At a recent "Man and Space" conference in the USSR, Shklovsky described a hesitant but unavoidable return to the "peculiar varient of the anthropomorphic (human characteristic) concept."

According to Shklovsky, the creation and evolution of life on Earth, and its development into an expanding technological civilization, is based on a coincidence of highly improbable circumstances. He presented arguments that the sun and Earth are likely to be an exception to the general rules of the galaxy, and went so far as to use the term "miracle" to describe our current existence.

Since the most visible feature of such civilizations as ours is expansion, and since we see no evidence of any other civilization expanding, Shklovsky concluded that there are no other similar civilizations. He did admit that certain intelligent species might either choose, or be forced by situations, to refrain from unlimited expansion throughout the galaxy. Either way, he added, it amounts to the same thing: We are alone in the galaxy.

The realization that humanity is at "the vanguard of matter" actually places heavier responsibilities on mankind, Shklovsky asserted. Although it does seem like a return to an anthropomorphic point of view, he explained, it allows scientists to better evaluate the relationship between humanity and the universe.

Soviets Survey Resources

The Soviet Union continued its program of Earth resources surveys from space with the launch of Soyuz 22, a few weeks after the Soyuz 21 space capsule returned to Earth. Following the end of the short Soyuz 22 flight, new manned visits to the Salyut 5 space station were anticipated.

After spending 49 days in orbit (most of the period aboard Salyut 5), cosmonauts Boris Volynov and Vitaly Zholobov landed safely in Central Asia. Their midnight landing, and cryptic Soviet comments about "fatigue" and "psychological problems of sensory deprivation", led many observers to suspect the mission had been cut short of its planned 90 day duration. Other specialists disputed this interpretation and concluded that the mission had landed after photographic surveys of Soviet land areas were curtailed by seasonal darkness.

The Salyut 5/Soyuz 21 mission was devoted primarily to photography of Earth from space for the discovery of new mineral deposits, the monitoring of river and air pollution, and the investigation of techniques for manned military reconnaissance from space. Biological and engineering experiments were also included as secondary goals.

To gain maximum advantage of Earth's eastward spin, spaceships are generally launched almost directly toward the east. Soviet satellites must head slightly north of this direction in order to avoid passing over Chinese territory. Launched from a latitude of about 46 degrees north, the satellites circle Earth at an inclination of about 52 degrees. This brings them over all territory between 52 degrees north latitude to 52 degrees south latitude.

When Soyuz 22 was launched on Sept. 15, newspersons at first assumed that cosmonauts Valery Bykovsky and Vladimir Aksyonov were going to hook up with the empty Salyut 5 laboratory. But tracking stations in the United States soon reported that the manned spacecraft was circling Earth in an orbit with an inclination of almost 65 degrees. This made a rendezvous with Salyut impossible.

Soviet announcements soon cleared up the mystery. Soyuz 22, Moscow said, was carrying a special East German Zeiss camera system for surveying Earth's surface in many wavelengths. The orbit allowed the crew to survey areas more than 1,000 miles farther north than the regions covered by earlier satellites.

The use of an East German camera system coincided with new reports of more extensive cooperation between the USSR and its satellite nations in space exploration. Cosmonaut corps commander Gen. Vladimir Shatalov, three-time space veteran, announced in Moscow that scientists and engineers from Poland, East Germany, Czechoslovakia, Bulgaria, Romania, Cuba and Mongolia would begin training for space missions on board three-man Soyuz capsules. The flights, to be commanded by Soviet astronauts, would begin in 1978.

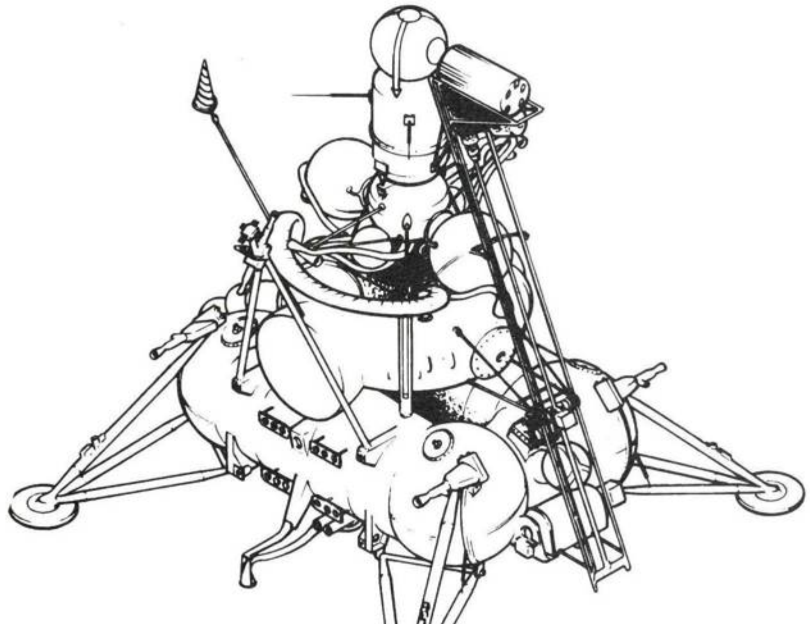
Before then, many new Soyuz flights are anticipated. Following the landing of Soyuz 22, the Soviet space program turned to the idea of a new visit to the Salyut space station which had been operating in an automatic mode since the departure of the Soyuz 21 cosmonauts. The new visit would probably include the first extravehicular activity (EVA, or spacewalks) in the Soviet manned space program in almost eight years.

In mid-October, Russian officials announced that there would be another two man crew launched to dock with the Salyut 5 space station. However, the Soyuz 23 crew was forced to abort the mission and return to Earth when the rendezvous equipment failed.

Cosmonauts Vyacheslav Zudov and Valeri Rozhdestvenskiy made the

Soviet *continued on page 58*

Luna 24 Features Improved Sample Assembly Design



Luna 24 is the third successful mission of its series, being preceded by Luna 16 and Luna 20. The earlier models featured a simpler design: a drill head that would swing down, collect a foot long sample and swing back up to the return capsule to store the sample (see Astro-News, December 1976). Luna 24's penetration to a depth of two feet (approximately two meters) was achieved by a rotary (drilling), percussion (hammering) operation — hammering through soft material until resistance was met, and drilling through hard material until the resistance was past. This required more leverage or bracing than was possible with the earlier swing arm. The solution was to mount the whole assembly rigidly against the side of the spacecraft, as this drawing shows. Twelve cakelike samples were collected, approximately five inches (10cm) in diameter and one inch (2.5cm) thick. Copyright© D.R. Woods.

Scientists Discuss Upcoming Pioneer and Mariner Missions

The prospect of finding a solid core within Saturn, tests for signs of a Saturnian magnetic field, and studies of the satellite Titan will be highlights of the Pioneer 11 flyby of the ringed planet, scheduled for 1979, and the Mariner Jupiter-Saturn missions of the early 1980s.

These were the main conclusions of a special joint meeting of the Royal Astronomical and Royal Meteorological Societies held in London, England in October 1976.

Details of the gravitational field of both planets have been studied traditionally by monitoring orbital motions of their moons. The "shape" of Jupiter's gravity well has also been refined by measurement of the Pioneer orbits as they were affected by the planet. University of Cambridge Prof. A.H. Cook stressed that all this evidence supports the opinion that Jupiter has the uniform field distribution expected from a fluid sphere, with only hydrodynamic compression of the central region. But Saturn seems, from satellite studies, to have a much smaller moment of inertia suggesting the presence of a compact, compressed central core.

Since Saturn is a smaller planet than Jupiter, the pressure in its center must be less — and even on Jupiter the central pressure is now thought to be sufficient to produce solid hydrogen, although hydrogen is probably compressed into a liquid metallic form there. So the solid Saturn core, if it exists, must presumably be composed of rocky material, surrounded by a sea of liquid metallic hydrogen and then by the visible atmosphere with its blanket of ammonia clouds.

Because the masses of the spacecraft are accurately known, changes in their orbits as they pass Saturn will give precise information about the shape of the planet's gravity well, and should settle the question of a rocky core inside Saturn. Equally important will be a final answer to the puzzle of whether Saturn has a magnetic field.

Jupiter has a huge magnetic field, affecting great volumes of space, with a "tail" stretching out past the orbit of Saturn. The presence of the Jovian field has been known for 20 years from radio observations of the radiation particles trapped in the Jovian magnetosphere. But it was only in 1975 that the first tentative observations of radio bursts from Saturn were published.

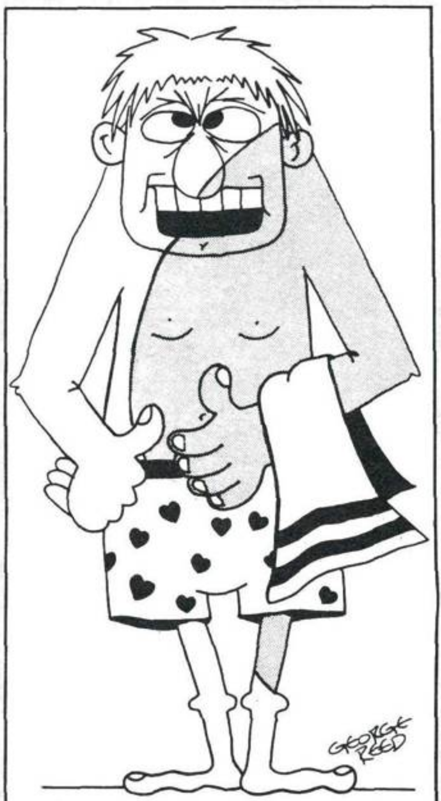
Interpreting this evidence, Dr. D. Stannard of Jodrell Bank suggested that Saturn's relative quietness in radio terms could be consistent with the presence of a magnetic field, since the Saturn ring system occupies the region of space where the planet's equivalent of our Van Allen belts would lie. If the rings sweep through this critical region, they will remove any charged particles that would otherwise accumulate and radiate through the synchrotron process. Jupiter has no such rings, so radiating Van Allen belts have formed without difficulty. But on Saturn, the only mechanism for radio bursts left would be the radiation from particles sliding down lines of magnetic force onto the poles — consistent with the nature of bursts now reported from observations with the IMP 6 satellite in Earth orbit, peaking at around one MHz.

Current estimates suggest a possible Saturnian field with a dipole moment (the measure of the relative ease in which polar molecules line themselves up with negative ends pointing toward the positive pole and positive ends pointing toward the negative pole) as much as 1/10 that of Jupiter. This was unsuspected even a couple of years ago, with the prospect of dramatic new results from the Pioneer 11 and Mariner Jupiter-Saturn magnetometers.

The third main focus of attention on these missions has a longer pedigree of Earth based study — the giant moon Titan, almost a planet in its own right, with an atmosphere denser than that of Mars today. The key puzzle for the probes to solve is why Titan retains a rich lacing of hydrogen in its atmosphere, when this light gas *should be* rapidly lost to space from its weak gravitational field.

The answer favored by Dr. Garry Hunt, UK Meteorological Office, is that the escaping gas forms a "ring" around Saturn in Titan orbit, so that although hydrogen constantly escapes, it is also constantly renewed. This hydrogen torus might even be detected before probes reach Saturn, through ultraviolet studies with the International UV Explorer, due for launch later this year.

Overall, the experts agreed the present state of knowledge about Saturn hints at spectacular developments from the coming missions, likely to rival the flood of new information returned from the two recent Jupiter probes.



"Never sunbathe during an eclipse!"

Soviet

continued from page 57

Soviet Union's first water landing in Lake Tengiz amid a snowstorm during darkness. There is speculation that the Soyuz was off course, necessitating the hazardous landing conditions. The craft landed 48 hours 6 minutes after being luanched from the Baikonur site in Soviet central Asia. The two cosmonauts will probably be sent into space again after the cause of the failure is isolated and corrected.

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PUBLISHER'S MEMO

Milwaukee, Wisc., Nov. 8, 1976 — Happy, Happy 1977! I sure hope the new year greets you well and carries you through to '78 with only minor knocks and bumps.

Everything is going fantastically well at ASTRONOMY and AstroMedia Corp. As a matter of fact, I've had a little more time than normal on my hands during the last three or four months, and have come up with a whole bunch of new ideas that I think you're going to flip over — so keep your eye on ASTRONOMY this year and we'll see if I'm right or all wet (or snow laden depending on where you're located).

Look out world—here we come!

Less frivolously for a second, the reason I've had extra "think" time recently is because I've just recovered from a serious illness which struck me in mid-August, and put me out of commission for a while. (It's a rotten way to take a vacation!) I won't bore you with medical jargon and details; the only fact you need even think about — which was the pride of my recovery — is that a magazine is not just a bunch of glossy pages with lots of ink and pretty pictures. A magazine is the talented people who run it to the dedicated service of its public (that's all of you out there). My pride stems from the fact that I created a "child" in 1973 which was/is able to continue in my absence without faltering.

And very sincerely, that means more to me/us than anything in the world!

On another front . . . . During the past seven months we changed circulation fulfillment services, and the changeover created problems which in turn generated a substantial increase in subscriber relations type problems. We apologize deeply if you were one of those who were inconvenienced, and promise things will be brighter in the future. As a matter of fact, Dave and John Sweeney at our new service bureau (two of the unsung heroes behind the ASTRONOMY scene) have promised us that as of the January 1977 issue, the majority of problems will have been corrected and any creepers that remain will hopefully be minor.

Heck, let's face it . . . ASTRONOMY — with 70,000 subscribers (nearly 3 times as many readers) — is getting to be a pretty big magazine. So if one of those problems becomes a major annoyance, we now have two Subscriber Relations people to banish your subscription blues. Rosemary Pickart is still with us waging fulfillment battles that would scare a dinosaur. And now, brand new to ASTRONOMY is **Jodi Groth**. . . .

When interviewed, Jodi said she wouldn't want to join ASTRONOMY's staff if her position in Subscriber Relations would be slow and monotonous; she was looking for variety and contact with people (chuckle, chuckle!). And she shall have it!

Jodi's duties are basically the same as Rosemary's. In taking the ASTRONOMY oath, she has promised to faithfully, diligently, and as expeditiously as possible troubleshoot and correct all problems/errors that may arise with your subscription. If, for example, your address is incorrect . . . your payment has not been applied to your new or renewal subscrip- renewal subscription . . . your magazine is delivered late or is damaged . . . or — even worse — it has mysteriously stopped arriving altogether . . . be sure to write or call either Jodi or Rosemary to let them know about your problem. Don't forget — *your* problem is *our* problem, as well. But we can't rectify it unless you let us know about it.

Jodi says she enjoys the publishing "busyness": She also helps fill orders for calendars, back issues, reprints, posters, indexes, etc. If you have delivery problems with any of these items, be sure to let Jodi — or Rosemary — know.

With this expanded Subscriber Relations department, we will continue to try to humanize/ personalize our service to you, our subscribers.

As if fulfillment weren't enough of a problem to to choke Moby Dick, the U.S. "Slowstal" Service has "improved on snail magazine delivery" to the extent that ASTRONOMY, mailed the middle of the month before issue date, is now delivered nationwide (sort of) by the middle or end of the issue date month. Second class mail is supposed to get 10 day national delivery. No offense, Mr. Jones — we still like you and the gang at the Milwaukee post office. But let's face it — there seems to be some "machinery" jammed somewhere in the system, and it's got to get fixed!

Anyway, the gist of this silly tirade is that we're trying to accommodate part of this delivery dilemma by:

1. Aiming really important observational details to events or objects that can be seen or occur later in the issue month.

2. Adding a Staff Artist, increasing editorial department staff and redistributing editorial workloads. This should enable us to back up our mailing dates still further.

3. Finally (and we hope most successfully), exploring new (to us) methods of nationally/internationally distributing ASTRONOMY so it gets to you faster: before — or at least by — the 1st of the issue month.

Let Rosemary and Jodi know if your delivery improves. After all, you don't have to have a problem to write to our Subscriber Relations department.

Moving onward — or backward in time in this case — perhaps you've noticed the beautiful color astronomical photographs taken by Bob Provin and Brad Wallis that we've been publishing in ASTRONOMY (almost from our first issue). Well, these guys are so good that AstroMedia Corp. financed an astrophotographic expedition for them to Australia to photograph the October 1976 total solar eclipse. (A few of their photos appear in Sky Almanac this month.) While in Australia, they also took some astrophotographs (in color) of sky objects that we, located in the northern hemisphere, can't see. (These objects are below our southern horizon and never rise into our southern sky where they could be photographed.) Keep your eye on ASTRONOMY where you'll see Bob and Brad's color photos regularly.

Regarding other new ASTRONOMY staff members besides Jodi, in editorial we have **Mary Jane Lamers**, who disco dances pretty darn good . . . .

You've probably noticed Mary Jane's name in the ASTRONOMY masthead in recent months; she is our (fairly) new Staff Writer and Astro-News editor.

A recent graduate of the University of Wisconsin - Oshkosh, she majored in journalism and minored in astronomy. An astronomy enthusiast for about 8 years, she essentially designed her own astronomy coursework to fill the gaps in her knowledge of the subject.

Mary Jane previously worked as a reporter and on the copy desk of the Oshkosh **Advance-Titan**. She has also been extremely active in the Society of Professional Journalists — Sigma Delta Chi.

In addition to handling Astro-News, Mary Jane edits some of our lead features and occasionally writes Sky Almanac. She also works closely with Richard Berry (our Technical Editor) and Henry Phillips (our Associate Editor) in suggesting/ selecting artwork or photographs to illustrate the articles in ASTRONOMY.

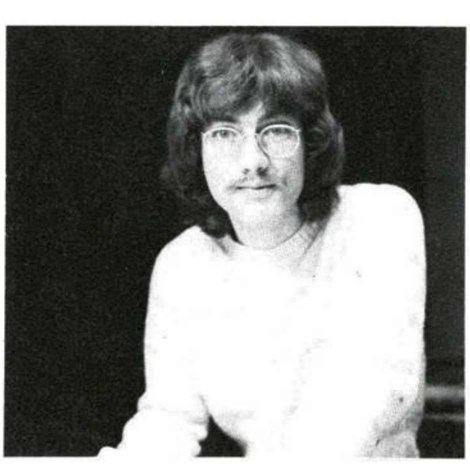
Also, we have a new editorial secretary — **Judy O'Dair** — who just recently got married. I don't know if she can disco dance well cause we haven't yet had my "official" recovery party. Even so, her new spouse might frown just a tad on such goin's on . . . .

As Editorial Secretary, Judy assists Kathy King in maintaining organization in our editorial department. In addition to rough typing manuscripts and filing, she handles correspondence for the editors: acknowledgement of submissions, acceptance or rejection letters for manuscripts, photographs, etc.

Some of Judy's time is spent cataloging materials for our reference library — a task which is teaching her far more about astronomy than what she learned while compiling a notebook on the subject in junior high school. (Her grade on the project was A+ + +.)

A graduate of the St. Cloud (Mn.) State College, Judy taught junior high school English and communications for five years before joining the ASTRONOMY staff. Her decision to change professional careers was a personal choice to enable her to gain insights into the publishing and writing fields.

Leastly but not lastly (or some "facsimiltude" thereof), we've hired **Mark Paternostro** as ASTRONOMY magazine's full time Staff Artist. Previously Mark was one of our free lance contributors; now he just sort of sits around skinnily airbrushing all day long, giving me severe guilt complexes about the hospital flab I've built up. For the 7.5 percent feminine minority of our subscribers out there, I don't know or care if he disco dances. But, if it matters to you, you can reach him here at ASTRONOMY. . . .



Mark works closely with our editorial staff in developing artwork for the pages of ASTRONOMY. Our newest employee, he will also work closely with our contributing artists, explaining our graphic needs and standards in artistic/astronomical jargon.

His father first introduced him to the world of art when he was a little tyke; young Mark won his first award for a Fire Prevention poster when he was in third grade. Throughout his youth, Mark's father stressed the fact that "you learn to draw by drawing".

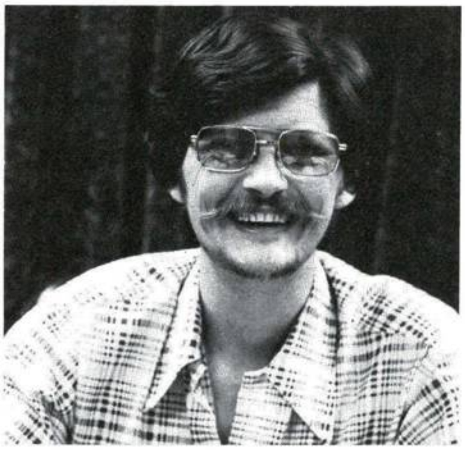
Mark attended the University of Wisconsin for several years as a Fine Arts student; his collateral coursework in biology and geology provided him with a solid background in the evolution of life and Earth. Interested in astronomy for as long as he can remember, he says he used astronomical imagery in nearly all of his early paintings. Outside reading and research led to his knowledge of the actual science of astronomy — and this educational process is continuing at the magazine.

Once again, to repeat my September 1976 Publisher's Memo invitation, if you're ever in Milwaukee stop in to see us. Not only would we love to show you our new offices, but you can also see many of the original cosmic paintings we've used in ASTRONOMY. Really, it's like touring an art gallery — but like none you've ever seen before! If you just "drop in" we'll try to find someone who can take you through, though it's best to phone ahead.

Actually, Milwaukee is a super town even just to visit. Not only do we have beer, bratwurst, Karl Ratzsch's and the Pfister Hotel, but we also have Oliver's Cabaret (the site of my "official" recovery party) with Lawrence the Legend and especially Zeb! We've also got one of the best classical FM stations (WFMR) in the country.

Enough of this month's Tom Foolery. It's great to be back at the helm!

The entire gang at ASTRONOMY joins me in wishing you a Joyful, Hopeful, Happy 1977!



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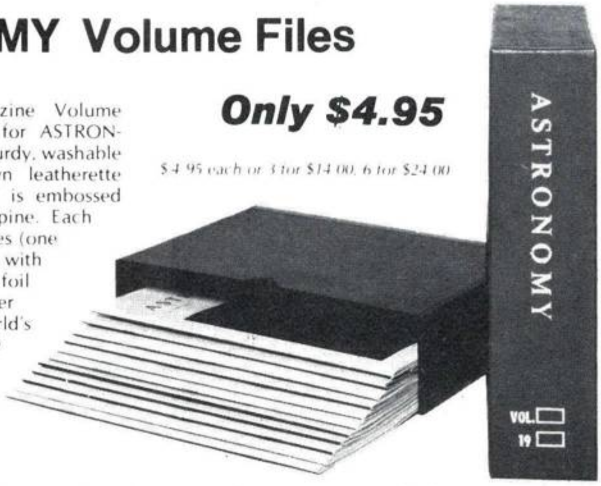

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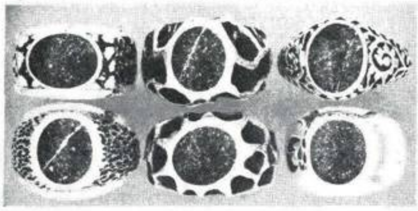

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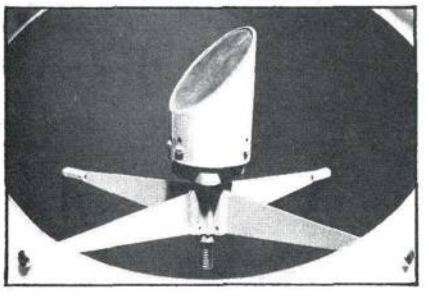

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Reader interest in back issues of ASTRONOMY magazine is higher than ever. As a result, our stock of back issues is swiftly dwindling. Below is a guide to ASTRONOMY back issues that are still available. For your convenience it is updated monthly; issues not listed are depleted. **The July 1976 History of American Astronomy issue is specially priced at $3.50 per copy plus postage.**

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*Not Yet Published

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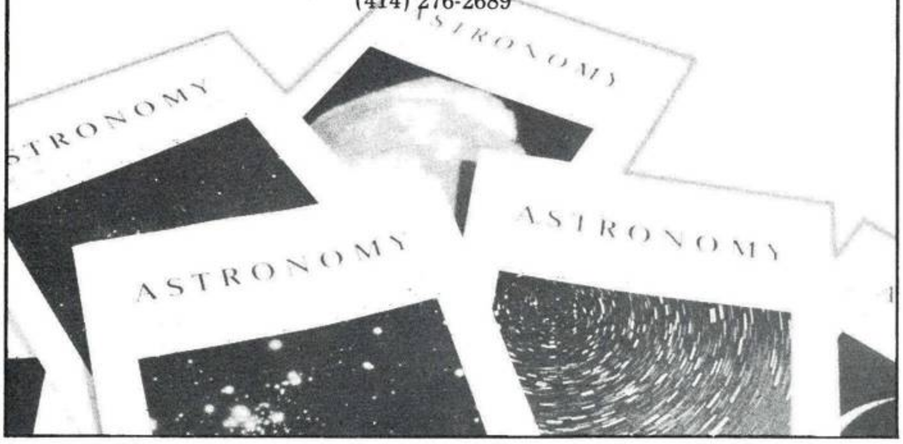

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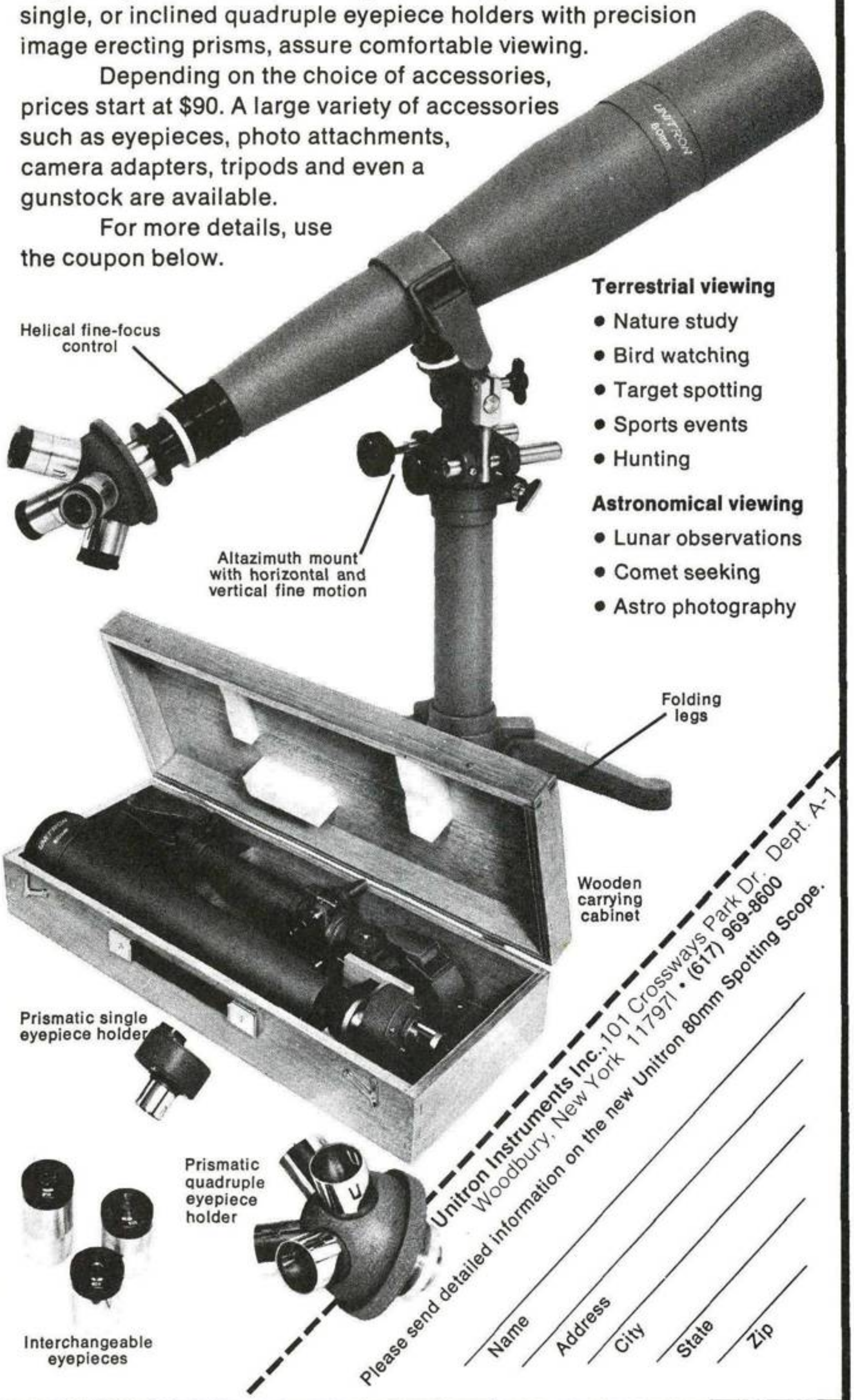
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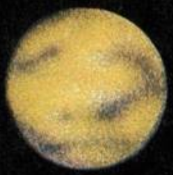
Ⓒ Ceres

Jan.	1	15
R.A.	12h40m	12h51m
Dec.	+8°30'	+8°28'
Mag.	+7.9	+7.6



Ⓐ Mercury

Jan.	1
R.A.	19h30m
Dec.	-20°15'
Mag.	+1.6

Ⓑ Mercury

Jan.	15
R.A.	18h30m
Dec.	-20°09'
Mag.	+0.7

Ⓜ Mars

Jan.	1	15
R.A.	18h03m	18h49m
Dec.	-24°04'	-23°42'
Mag.	+1.6	+1.5

Ⓝ Neptune

Jan.	15
R.A.	16h56m
Dec.	-21°09'
Mag.	+7.7

SUN

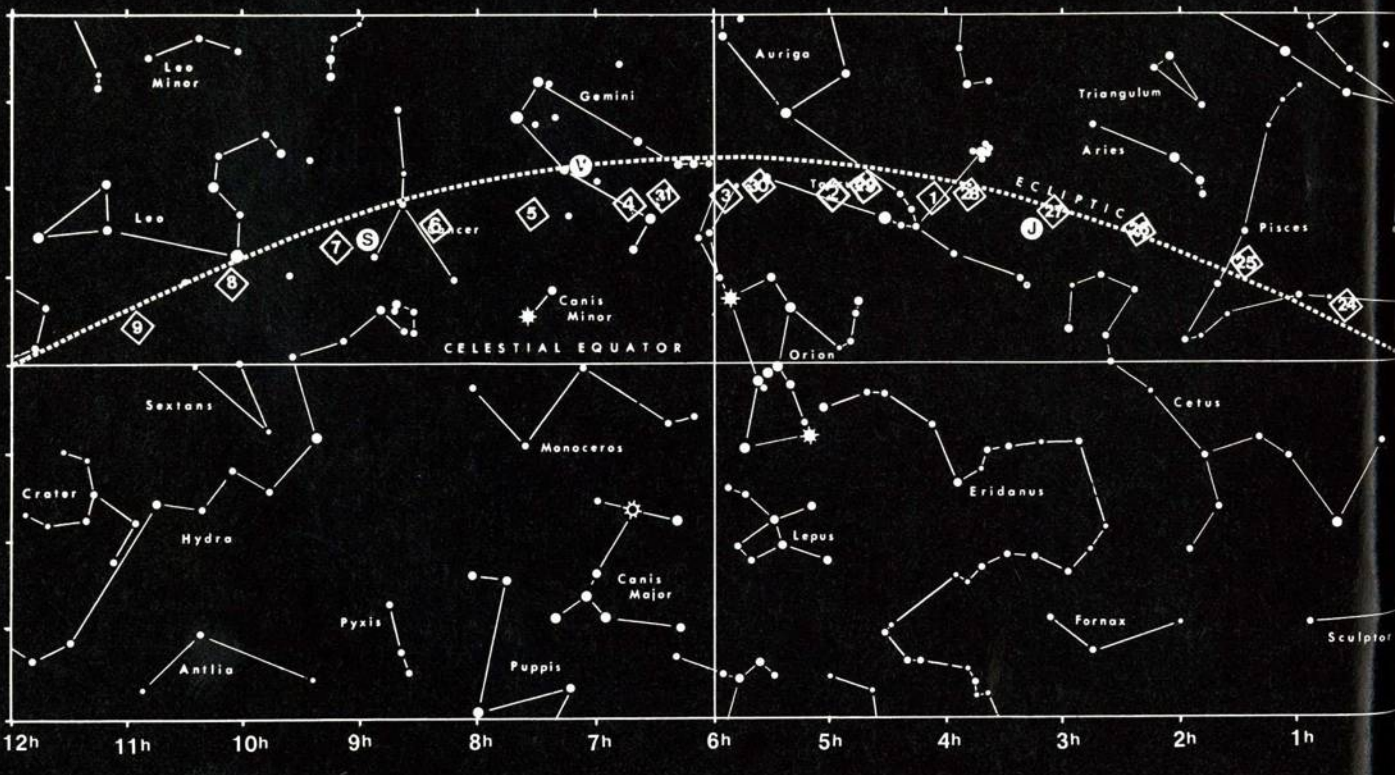
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

Jan.	1	15
R.A.	9h14m	9h10m
Dec.	+16°57'	+17°15'
Mag.	+0.3	+0.1

Ⓤ Uranus

Jan.	15
R.A.	14h34m
Dec.	-14°41'
Mag.	+5.7


Leo Minor
Gemini
Auriga
Triangulum
Aries
Leo
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ECLIPTIC
Pisces
Canis Minor
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Orion
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9
8
7
S
6
5
4
31
3
30
2
29
1
28
J
27
26
25
24
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

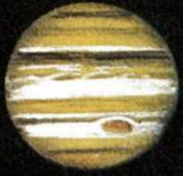
January 1977

Ⓥ Vesta

Jan.	1	15
R.A.	7h27m	7h12m
Dec.	+22°34'	+23°44'
Mag.	+7.2	+7.2

Ⓟ Pluto

Jan.	15
R.A.	13h17m
Dec.	+10°12'
Mag.	+14



Ⓙ Jupiter

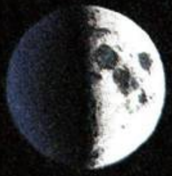
Jan.	1	15
R.A.	3h17m	3h15m
Dec.	+17°11'	+17°10'
Mag.	-2.2	-2.1

Ⓨ Venus

Jan.	1
R.A.	21h59m
Dec.	-13°55'
Mag.	-3.9

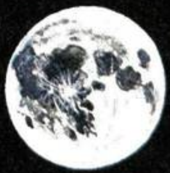
Ⓩ Venus

Jan.	15
R.A.	22h56m
Dec.	-7°23'
Mag.	-4.0



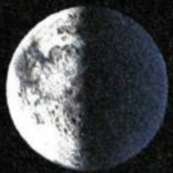
First Quarter

January 27



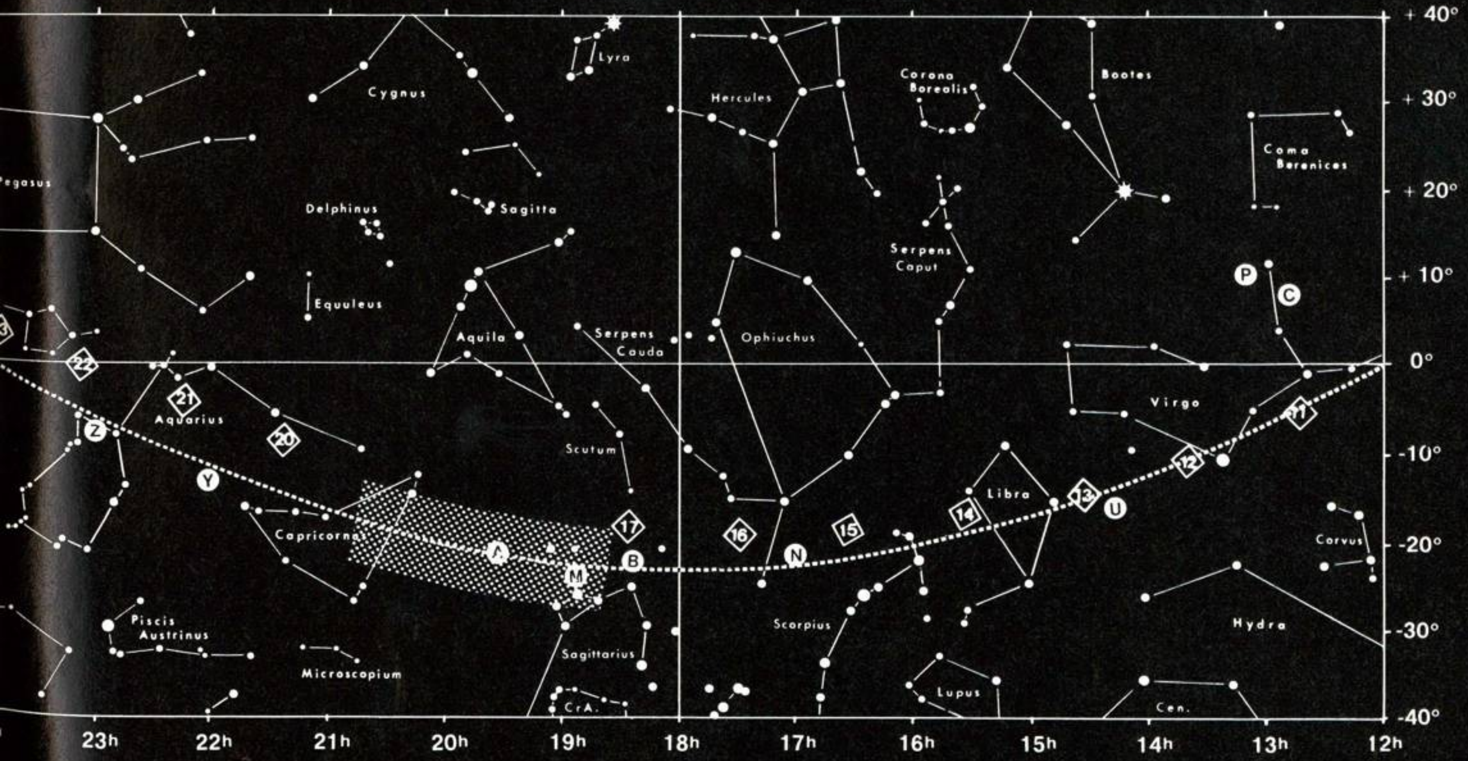
Full Moon

January 5



Last Quarter

January 12



+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h
Pegasus
Cygnus
Lyra
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Aquarius
Scutum
Virgo
Capricornus
Libra
Corvus
Scorpius
Hydra
Piscis Austrinus
Microscopium
Sagittarius
CrA.
Lupus
Cen.
Z
Y
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22
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11

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

ASTRONOMY

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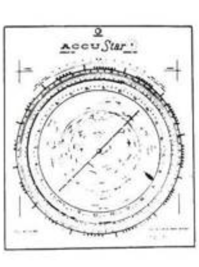

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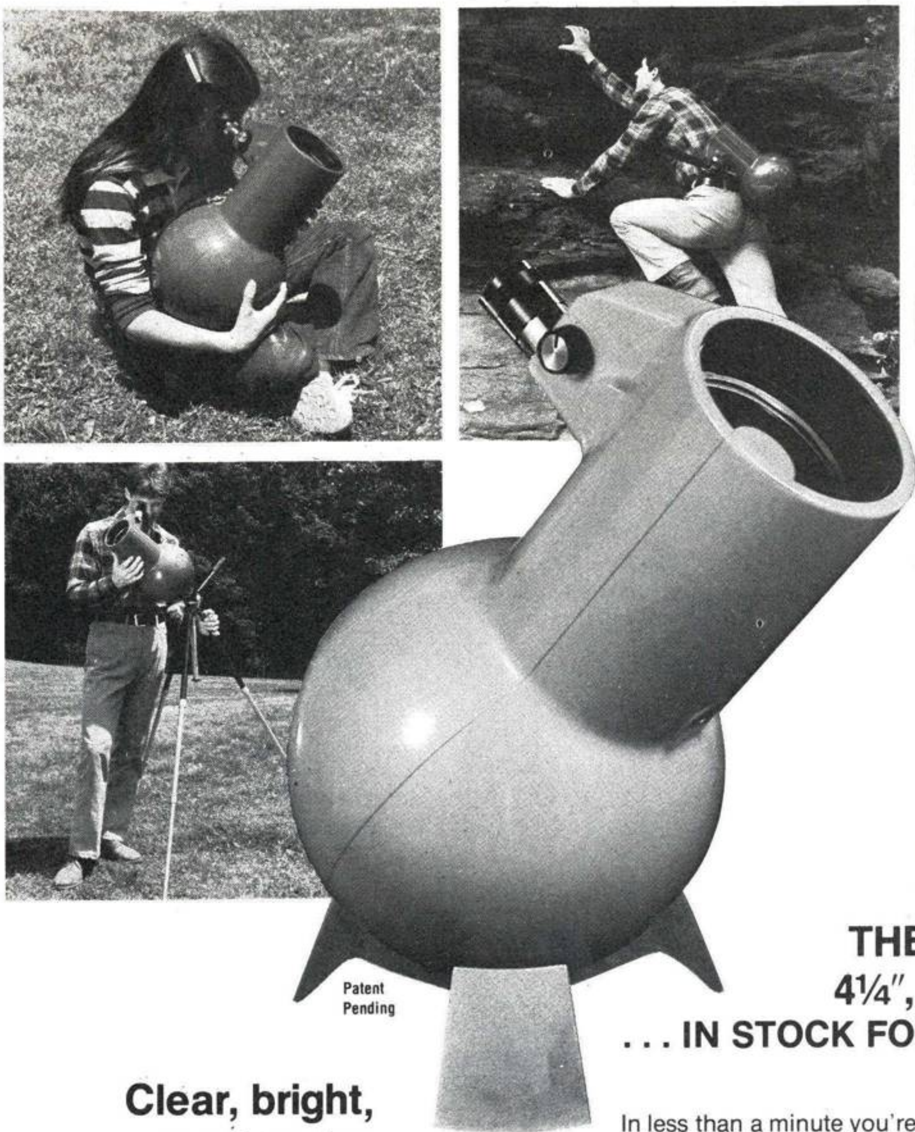

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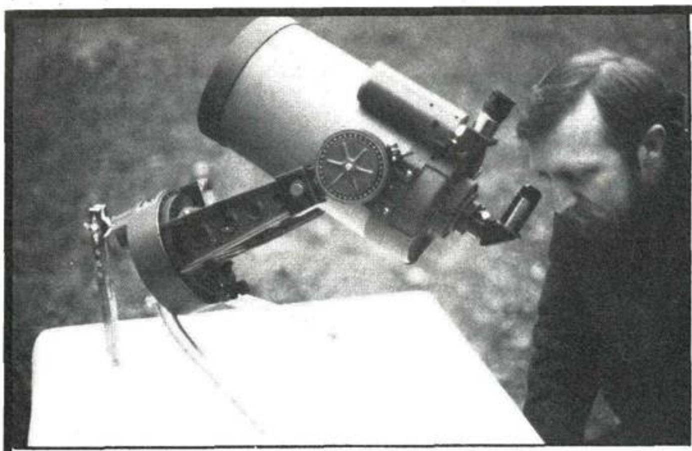

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STAR DOME

JANUARY

by
James Mullaney and Henry J. Phillips

Near the end of Lewis Carroll's **Alice's Adventures in Wonderland**, the King of Hearts advises his herald to "Begin at the beginning and go on till you come to the end: then stop." The neophyte who is just starting his study of astronomy in general, and the constellations in particular, might find this a good bit of advice to follow. Although it can't be obeyed in its entirety (once embarked on the fascinating world of astronomy, we soon learn that there is no stopping point), we find there's no better time to begin learning the constellations than at the beginning of the year — simply because the January stars are brighter than those of any other month.

Brightest of all is Orion; with two first magnitude stars (Rigel and Betelgeuse) and five of second magnitude, Orion has no match anywhere in the sky. The stars of Orion have perhaps the most immediately distinctive pattern of any single constellation, and it has figured importantly in the sky mythology of every culture in every age.

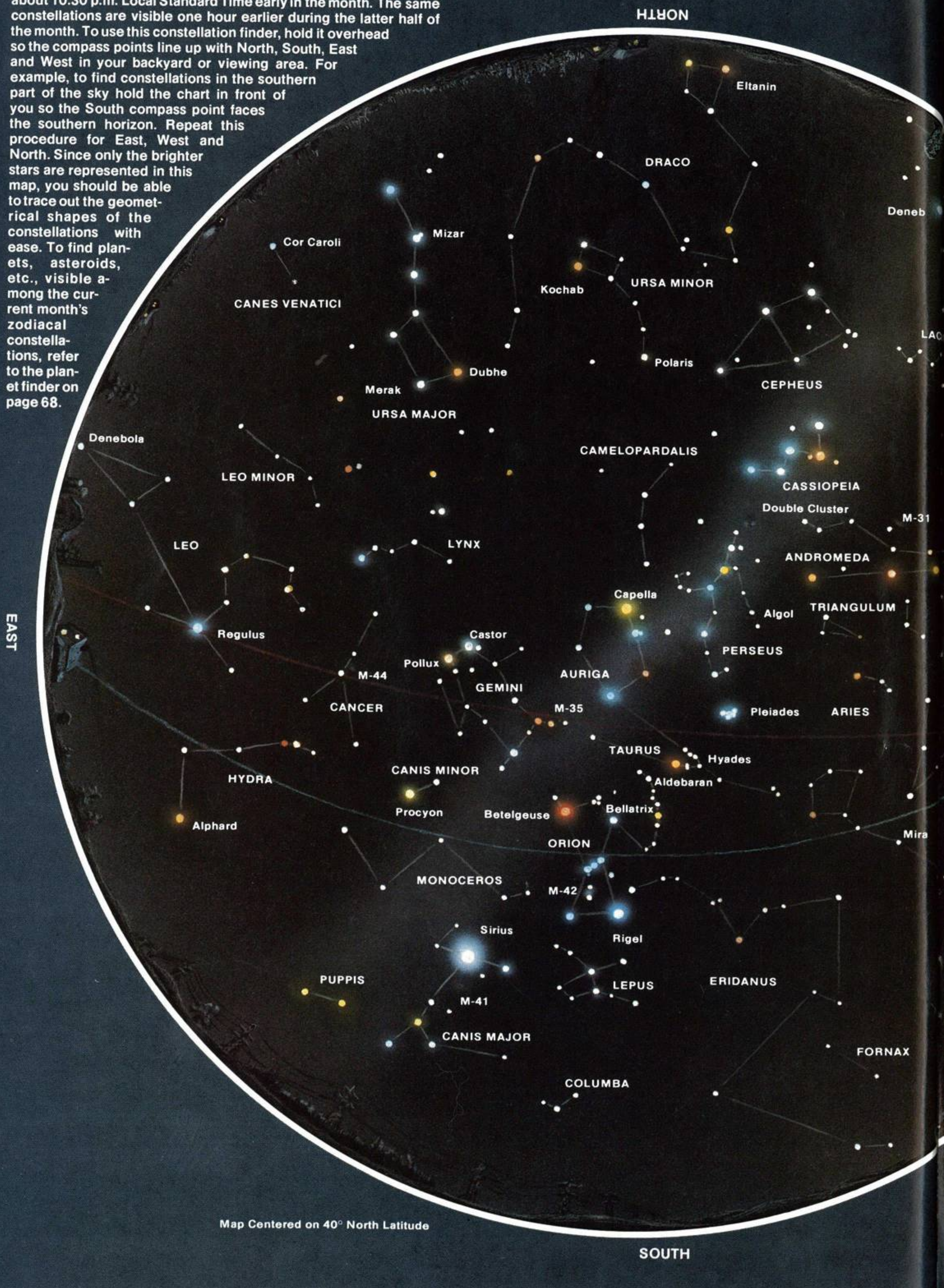
Rigel and Betelgeuse are two members of a figure that is usually called the Great Circle, consisting of seven first magnitude stars crowded into a relatively small section of the sky. Actually, the circle more closely resembles an elongated, lopsided hexagon, with six stars placed at the corners and one, slightly off-center, inside. Betelgeuse is the middle star and Rigel is at the southwest corner; the others (moving counterclockwise) are Aldebaran in the constellation Taurus, Capella in Auriga, Pollux in Gemini, Procyon in Canis Minor, and Sirius, the brightest of all stars, in Canis Major.

These seven first magnitude stars dominate the six constellations to which they belong. Frequently overlooked, therefore, is the presence within these same six groups of no less than 13 stars of second magnitude — each as interesting in its own way as any of its brighter companions. Let's run through these stars one by one — beginning, again, with those in Orion.

Betelgeuse and Rigel are at opposite ends of the rectangle that represents Orion; the other two corner stars are Bellatrix (Gamma Orionis) in the upper right and Saiph (Kappa Orionis) at lower left. Both stars belong to spectral class B, but Bellatrix is the much nearer of the two. Lying at a distance of 470 light-years, it is one of the nearest of the bright stars in Orion, while Saiph is the most distant — an incredible 2,100 light-years away. This is one reason why Bellatrix (magnitude 1.64) appears brighter than Saiph (magnitude 2.06).

Within the rectangle are the three stars of Orion's belt; from right to left, they are Delta, Epsilon and Zeta Orionis, which are named Mintaka, Alnilam and Alnitak. These names mean, respectively, the belt, the string of pearls, and the girdle. Alnilam and Alnitak are the same distance from us (1,600 light-years) and have almost the same magnitude (1.70 and 1.79); Mintaka, 100 light-years closer to Earth, is an eclipsing variable with a period of about 5 days 17 hours. Its magnitude ranges from

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 68.


NORTH
Eltanin
DRACO
Deneb
Cor Caroli
Mizar
Kochab
URSA MINOR
CANES VENATICI
LAC
Polaris
Dubhe
Merak
CEPHEUS
URSA MAJOR
Denebola
CAMELOPARDALIS
LEO MINOR
CASSIOPEIA
Double Cluster
M-31
LEO
LYNX
ANDROMEDA
Capella
Algol
TRIANGULUM
EAST
Regulus
Castor
Pollux
PERSEUS
M-44
AURIGA
GEMINI
CANCER
M-35
Pleiades
ARIES
TAURUS
Hyades
CANIS MINOR
Aldebaran
HYDRA
Procyon
Betelgeuse
Bellatrix
Alphard
ORION
Mira
MONOCEROS
M-42
Sirius
Rigel
PUPPIS
LEPUS
ERIDANUS
M-41
CANIS MAJOR
FORNAX
COLUMBA
SOUTH

Map Centered on 40° North Latitude

CYGNUS
TA
PEGASUS
Alpheratz
PISCES
CETUS
Deneb Kaitos
WEST

Map by Adolf Schaller

2.20 at maximum to 2.35 at minimum. Alnitak is also a double star; the companion lies about three seconds of arc from the primary.

Moving north, we come to Elnath (Beta Tauri), the second brightest star in Taurus the bull; it marks the tip of one of the animal's horns. Long thought of as belonging to both Taurus and Auriga the charioteer, Elnath was officially assigned to the former in 1930 by the International Astronomical Union — although we still need it to complete the pentagon that is Auriga's distinguishing shape. At magnitude 1.65, Elnath is almost equal in brightness to Bellatrix, but is somewhat nearer (300 light-years away).

Still farther north, almost due east of Capella, is Menkalinan (Beta Aurigae). This blue-white star, 88 light-years distant, shines at magnitude 1.86 — no match for nearby Capella, but quite bright in its own right. Menkalinan marks the charioteer's shoulder; its beautiful name has this prosaic meaning.

Farther east is the only one of these second magnitude stars that is equally as famous as any of its first magnitude neighbors. This is Castor (Alpha Geminorum), forming with Pollux the Gemini twins. Actually a double star with components of magnitudes 1.97 and 2.95, Castor appears to the naked eye as a single star of magnitude 1.58, only slightly dimmer than Pollux. The pair also has a ninth magnitude companion, and each of these three is a spectroscopic binary — making Castor a system of six stars altogether!

Castor and Pollux are the best known examples of stars that have suffered from a confusion of nomenclature. In 1603, Johann Bayer's star catalog, **Uranometria**, assigned letters of the Greek alphabet to the stars of each constellation, in order of brightness. Castor was designated Alpha Geminorum, and Pollux was labeled Beta. But Pollux is brighter than Castor, and vast numbers of writers and commentators have speculated that one of the two stars has undergone a change in brightness since Bayer's day. Unfortunately, this exciting idea is the result of a misunderstanding of Bayer's working method. In assigning Greek letters, Bayer *did not* go in strict order of brightness; rather, he first labeled all the first magnitude stars in a constellation, followed by all the second, all the third, and so on — usually moving from the "head" of the figure as traditionally depicted. When a figure such as Gemini had more than one head, Bayer moved from west to east. Since Bayer lived long before the invention of photometry and accurate magnitude measurements, he considered both Castor and Pollux as first magnitude stars, and named them accordingly. The same method was applied to the stars of the Big Dipper (which are designated Alpha through Eta, moving from the great bear's head to its tail) because Bayer thought of them all as second magnitude stars. Therefore, we need not imagine that steady, nonvariable stars like Castor and Pollux have undergone marked brightness alterations in less than 400 years.

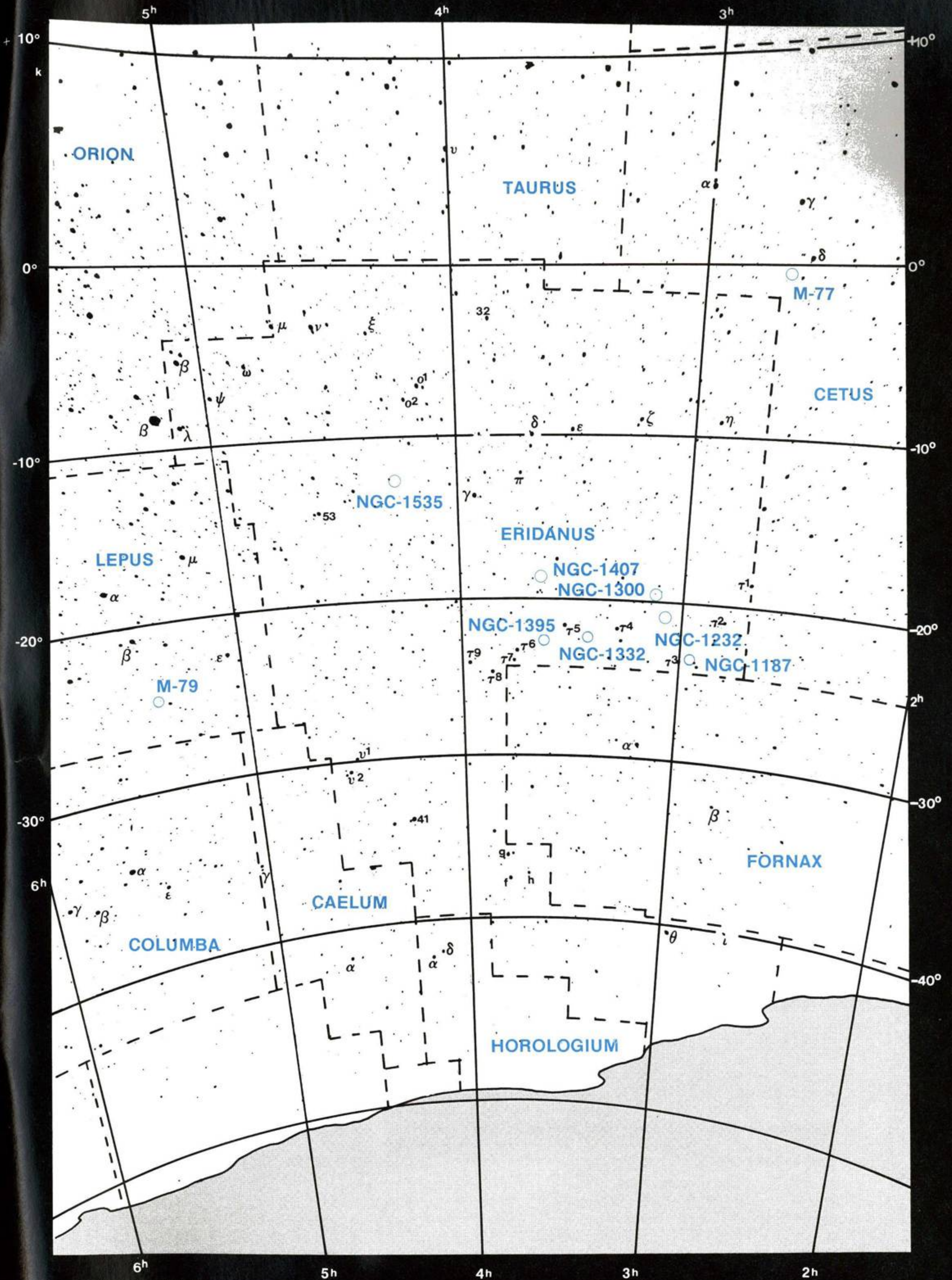
Another second magnitude star in Gemini lies between the twins and Betelgeuse. Gamma Geminorum, named Alhena, shines at magnitude 1.93 and is 105 light-years away. Like Menkalinan, Alhena is a blue-white star of spectral class A.

Canis Minor, the proprietor of Procyon, contains no second magnitude stars, but Canis Major, farther south, has four. A short distance west of blazing Sirius is Murzim (Beta Canis Majoris), a blue giant about 750 light-years distant, shining at magnitude 1.93. The other three stars form a small triangle southeast of Sirius. The eastern star in the triangle is Aludra (Eta Canis Majoris), and it barely qualifies as a second magnitude star, for its magnitude is only 2.46. But this seemingly low brightness is caused by Aludra's enormous distance from Earth of 2,700 light-years. Aludra is actually a blue supergiant with an absolute magnitude of -7.1. Only slightly nearer than Aludra is Wezen (Delta Canis Majoris), the topmost star in the triangle. Wezen is a white supergiant that lies 2,100 light-years away; it shines in our sky at magnitude 1.85.

The most interesting star in this small triangle is Epsilon Canis Majoris, named Adhara. This blue star is about 680 light-years from Earth, and its magnitude has not been determined with any certainty; estimates range anywhere from 1.6 to 1.42. If the latter figure is correct, Adhara becomes a member of the exclusive first magnitude club, making a total of 22 such stars in our sky. Canis Major would then join Orion, Centaurus and Crux as one of the very few constellations containing more than one of the brightest stars.

One more winter constellation has a first magnitude star as its brightest member. Unfortunately, the star doesn't rise high enough above the horizon for observers in most of the United States ever to get a chance to see it. The constellation is Eridanus, and its brightest star — Achernar, the end of the river — has a declination of -57 degrees.

Eridanus is named after the mysterious river in Greek legend which no human being had ever seen. It is a long, wandering constellation that rises near Rigel, moves west toward Cetus, makes a long curving swoop to the southeast, and then doubles back and flows below the horizon in mid-northern latitudes. Most of the visible portion of the constellation is quite dim, with only a few third magnitude stars to mark its boun-


5h
4h
3h
+10°
0°
-10°
-20°
-30°
-40°
6h
2h
ORION
TAURUS
CETUS
M-77
ERIDANUS
NGC-1535
LEPUS
NGC-1407
NGC-1300
NGC-1395
NGC-1332
NGC-1232
NGC-1187
M-79
FORNAX
CAELUM
COLUMBA
HOROLOGIUM
6h
5h
4h
3h
2h

Photograph by Brad Wallis and Robert Provin
Map by Richard Berry

daries. One of these near Rigel, is Beta Eridani; its name, Cursa, is from an Arabian title meaning "the footstool of the central one" (Orion). Thus, no matter how far we wander in the winter sky, we inevitably return to glorious Orion in the end.

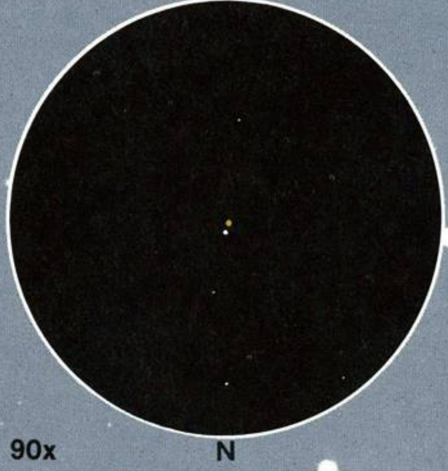
Close-Up

Eridanus Region

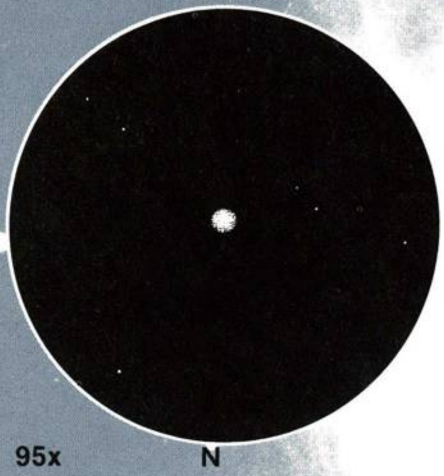
"The subequatorial areas here are not especially notable for wizardries, tho offering some broad sweeping in clear skies. The south flowing constellation of the classic River Po reaches down to within 30-1/2 degrees of the pole, beaconed by the flashing supersun Achernar." Thus are we introduced by Barns to the cosmic adventureland of Eridanus.

There is indeed much to see here, despite the rather low altitude that this meandering constellation attains for northern hemisphere observers; our table of selected objects contains several real showpieces. Even binoculars will reveal some fine sights, such as an attractive stellar grouping around Beta and a pair of orange stars below Nu. Another interesting area is the chain of stars marked by Tau 6, 7, 8 and 9. Barns refers to this region as a "zone of jewels of many hues and geometrical formations; with clear horizon a fine pageant."

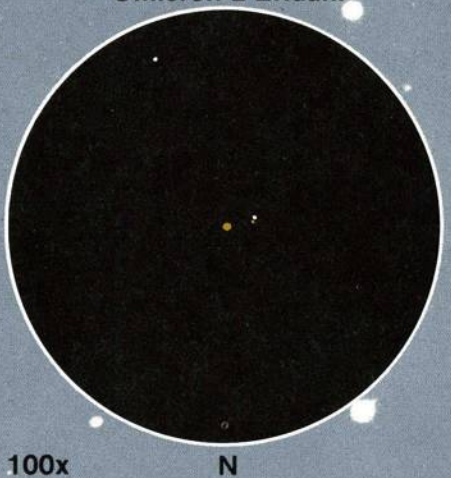
32 Eridani



NGC-1535



Omicron 2 Eridani



Upper left: 32 Eridani is a beautiful yellow/green double star; its colors are intense and easily seen. This view, as seen through a four inch reflector at 90 power, shows the binary's hues well. The field of view is 1/2 degree. Lower left: Omicron 2 Eridani is a triple of three contrasting colors. The bluish star is the most easily observed white dwarf star in the heavens. The drawing shows the system as seen through an eight inch reflector at 100 power; the field of view is 1/2 degree. Above: NGC-1535, a planetary nebula, is shown here as seen through a six inch reflector at 95 power. The nebula's icy radiance is visible in moderate to large sized instruments. The field of view is 1/2 degree. Drawings by James Mullaney.

Theta (θ) Eridani

On such a night of "clear horizon" (good transparency), look for one of the wonders of the deep south: the brilliant white binary star Theta Eridani. A line from Alnitak through Rigel in neighboring Orion, extended southwest nearly 45 degrees, points to Theta.

Although it's only about 10 degrees above the southern horizon at meridian transit for most United States observers, Theta is well worth the effort needed to find it. This blazing duo consists of 3.4 and 4.4 magnitude suns eight seconds of arc apart, and is easily split with a three inch refractor at 45 power when seeing (image steadiness) is good.

Few observers ever venture far enough south in the sky to bother looking for Theta — yet this neglected object ranks as one of the brightest and finest pairs to be found anywhere. Why not introduce yourself the next dark clear night?

32 Eridani

Should you fail to pick up Theta from your observing site, you can find ample compensation in a magnificent tinted duo much higher in the sky. This is 32 Eridani (often designated w Eridani on star charts), situated about 10 degrees due north of third magnitude Gamma, the brightest star in the area.

This lovely pair was discovered in 1781 by Sir William Herschel — and how surprised he must have been! Made up of 5.0 and 6.3 magnitude stars standing some seven seconds apart, this double is easily separated in three and four inch telescopes even at low power. Medium apertures and magnifications optimize the striking color contrast, as shown in our drawing.

Virtually all observers, both past and present, have seen the hues as brilliant yellow and blue-green, for they are intense and definite. Most descriptions list the stars as topaz and green, while Smyth said it was "topaz yellow, sea green or flushed blue". Secchi called this pair "magnifici, superbi", and Pickering included it in his exclusive list of the sky's 60 finest objects. Even Barns was impressed: "Emerald and topaz gems — one of the redeeming features of this somber region."

The actual spectral types of the primary and its companion are G and A, respectively, agreeing well with the visual impression. (Harvard astronomer

Selected Objects — Eridanus Region

Object	Type	Mag.	Size/ Sep.	R.A. (1950)	Dec.
ERIDANUS					
*θ (Theta)	★2	3.4,4.4	8"	02^h56^m	-40°30'
NGC-1332	El	10	3' x 1'	03^h24^m	-21°31'
*ϵ (Epsilon)	★N	3.7	—	03^h31^m	-09°38'
f	★2	4.9,5.4	8"	03^h47^m	-37°46'
* 32	★2	5.0,6.3	7"	03^h52^m	-03°06'
* NGC-1535	Pl	9.3	20"x17"	04^h12^m	-12°52'
*o^2 (Omicron 2)	★3	4.5,9.6,11	83", 8"	04^h13^m	-07°44'
55	★2	6.7,6.8	9"	04^h41^m	-08°53'

* Detailed in Close-Up

★2,3 = Double, Multiple Star
★N = Nearby Star
Pl = Planetary Nebula
El = Elliptical Galaxy
Mag. = Magnitude
Sep. = Separation

Donald Menzel considers class A stars as green in tint.) They are about 300 light-years distant from us.

As a rule, winter skies lack the colorful double stars seen at other seasons, but 32 Eridani is a definite exception. Check it out during your next observing session!

Omicron 2 (ο) Eridani

We move now from a contrasty double to a unique triple system unknown to most astronomy enthusiasts. This is Omicron 2 Eridani, fainter member of the Omicron pair and visible to the unaided eye seven degrees southeast of 32 — or an equal distance northeast of Gamma.

Also discovered by Herschel just two years after finding 32 Eridani, Omicron 2 consists of 4.5 and 9.6 magnitude stars a wide 83 seconds apart. The fainter star is itself double, having an 11th magnitude companion just eight seconds away at present. The colors here are orange, blue-white, and rose or reddish white as shown in our drawing made with an eight inch reflector. In this case, the larger the scope the better the view (as long as sky conditions are good).

As a triple star, Omicron 2 ranks poorly and we might not have featured it but for an important and unusual fact. The bluish 9.6 magnitude component is a member of that rare and strange class of stars known as white dwarfs — degenerate suns nearing the end of their incredibly long cosmic lives. As such, Omicron 2-B (as it is officially designated) is the most readily observable white dwarf star in the sky — much easier for smaller instruments than the famed companion to Sirius in nearby Canis Major.

The Omicron 2 system is among the nearest stars to us, at a distance of just under 16 light-years. This proximity partly accounts for the visibility of the dwarf star. Another important feature is that the B-C pair is in orbital motion about each other, having a period of about 250 years. This allows scientists to directly measure the mass of a white dwarf — to actually "weigh-in" a member of this rare breed of star. At times, the B-C pair's motion brings them to within two seconds of each other.

All three stars in the Omicron 2 system are moving through space together as a family. Their respective spectral types in order of brightness are K, WdA and M, again agreeing with the visual hues. Smyth calls the bright pair orange and sky blue, and Webb dubs Omicron 2 as a "most interesting ternary".

Here, then, is a unique opportunity for the observer to see an aged and dying star — one that basked in thermonuclear glory long before our sun appeared on the scene.

NGC-1535

We turn our attention now to a real deep sky lover's type of object — the lonely planetary nebula NGC-1535. You can pick this up by sweeping an area of sky four degrees east of Gamma, our trusty guide star for this month's region. Use a low power eyepiece on your telescope itself rather than the finder; the background is sparse here and most finders will fail to show the nebula.

Yet another of the discoveries made by Herschel during his majestic sweeps of the heavens, NGC-1535 measures 20 by 17 seconds in size (nearly circular) and shines at magnitude 9.3. Its nucleus is occupied by a 12th magnitude star. Some observers give this object's size as 30 seconds; it does look larger than the catalog figures suggest.

One modern writer has said of NGC-1535: "Like all planetaries, it is just a hazy dot in the sky . . . don't bother unless you have at least eight inches aperture." We can hardly agree with this, for attentive observation with even a three or four inch telescope reveals this and many other members of its class to be intriguing subjects. A six inch reflector at medium power shows this object's eerie, cold, bluegray disk shining in isolated splendor, as indicated in our drawing.

Comments by various observers hint at NGC-1535's appeal. Barns, for example, said: "Bright planetary nebula, with central star. Unique, visible with low powers. Well worth the search." Menzel mentions a bright inner ring and a faint outer one, while Bernhard, Bennett and Rice called this nebula "very fine; bright and grayish".

The most complete account is that of Webb: "Planetary, bright and round with low powers of 3.7 inch (refractor), but not bearing magnifying. Lassell has described it as the most interesting and extraordinary object of the kind he had ever seen: an 11th magnitude star standing in the center of a circular nebula, itself placed centrally upon a larger and fainter circle of hazy light. D'Arrest did not see this, but thought nucleus excentric, edges resolvable, and color light blue, as Earl of Rosse, who makes nucleus granular."

Other observers have mentioned that the nucleus is not perfectly central, but displaced toward one edge of the nebula. Astronomy enthusiasts with large instruments would have the advantage here. On the other hand, very small scopes may reveal the curious flickering effect we have mentioned for the Ring nebula (M-57) and other planetaries in past Star Domes. Why not try to confirm some of these reported features with your own telescope?

For best results, observe NGC-1535 when it is on the meridian and therefore at its highest point in the sky. Also, those rare nights having both good seeing and transparency will allow optimum viewing at high magnifications.

While we normally stress low powers and wide fields of view for deep sky work, certain types of objects need more amplification in order to be well seen. Close double stars are one example, and the generally tiny planetary nebulae are another. Try using 50 power per each inch of telescopic aperture — 200 on a four inch, 300 on a six inch, etc. Provided seeing is good, this will result in optimum image scale and resolution in probing the secrets of objects like NGC-1535. (Herschel himself often used very high magnifications on selected subjects.) A good achromatic Barlow lens is a definite help in reaching such high relative powers.

NGC-1535 has a unique and strange allure all its own. Despite the cold of winter nights, it can keep you at the eyepiece for long spells, pondering its unearthly mysteries. Once its acquaintance is made, you'll find yourself frequently returning the visit — even though it's a journey of more than 2,000 light-years or 12 quintillion miles!

Epsilon (ε) Eridani

We end our excursion on the celestial river with a final stop at one of the perhaps most important stars anywhere in the sky. This is 3.7 magnitude Epsilon Eridani, situated slightly more than two degrees west of third magnitude Delta.

This object is an orange K type sun, and one of the very nearest stars to us — just 10.7 light-years away. As such, its physical characteristics have been intensely studied by astronomers.

By itself, it would not attract attention from the visual observer, for it is not double, nor variable or even highly tinted. As so often happens in appreciating the beauty and grandeur of the night sky, we must see with our mind as well as our eye. Epsilon's importance and significance lies in what the glow of light in the eyepiece represents.

In this case, Epsilon Eridani is one of the Ozma stars — those exciting solar neighbors suspected of having planets. This object was monitored in 1960 for extraterrestrial radio signals; today it is again on the search list of the mammoth Project Cyclops program, just getting under way.

Epsilon's age, size, composition, luminosity, temperature and slow axial rotation all favor the possibility of it harboring a solar system like our sun's. Truly, it is worth the observer's thoughtful scrutiny during an exploration of this region of the sky. As we stare at this sun's warm glow across the depths of interstellar space, we cannot help but wonder if others may be looking back at us.

As Lee DuBridge has said: "Either mankind is alone in the galaxy, or he is not; either alternative is mind-boggling."

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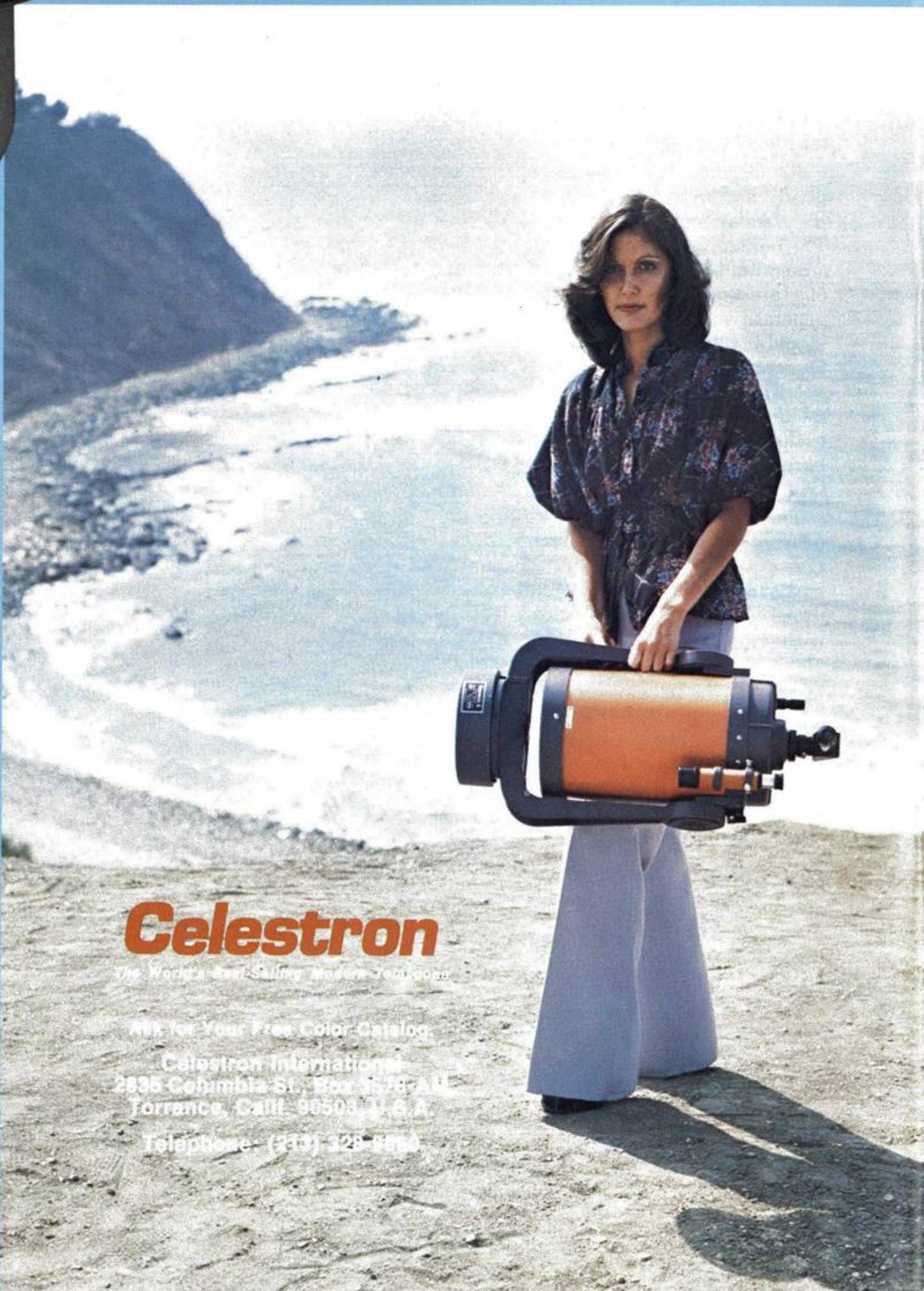

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